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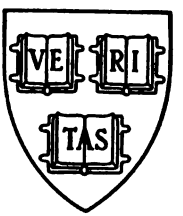

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OF THE

HOUSE OF REPRESENTATIVES

FOR THE

SECOND SESSION OF THE FIFTY-FIRST CONGRESS.

1890-'91.

WITH INDEX.

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WASHINGTON, D. C., *September*, 1890.

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1890

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UNITED STATES GEOLOGICAL SURVEY
J. W. POWELL, DIRECTOR

THE GREENSTONE SCHIST AREAS

OF THE

MENOMINEE AND MARQUETTE REGIONS OF MICHIGAN

A CONTRIBUTION TO THE SUBJECT OF DYNAMIC METAMORPHISM IN ERUPTIVE ROCKS

BY

GEORGE HUNTINGTON WILLIAMS

WITH AN INTRODUCTION BY

ROLAND DUER IRVING

WASHINGTON
GOVERNMENT PRINTING OFFICE
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LETTER OF TRANSMITTAL.

UNITED STATES GEOLOGICAL SURVEY,
LAKE SUPERIOR DIVISION,
Madison, Wisconsin, February 10, 1888.

SIR: I have the honor to transmit herewith, for publication as a bulletin of the Survey, a paper, by Prof. George H. Williams, of Baltimore, Maryland, on The Greenstone-Schist Areas of the Marquette and Menominee Regions of Michigan.

The exact object and bearing of the work thus accomplished by Prof. Williams I have set forth in an explanatory and historical note prefixed to his memoir.

I am, sir, very respectfully, yours,

R. D. IRVING,
Geologist in Charge.

Hon. J. W. POWELL,
Director U. S. Geological Survey.

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EXPLANATORY AND HISTORICAL NOTE.

By Roland Duer Irving.

At quite a number of points in the Lake Superior region occur peculiar schistose rocks, which combine with a prevalent fine grain a general tendency to greenish color. Besides occurring here and there more or less confusedly mingled with masses of granite and other rocks, these greenish schists occur also in large continuous areas, which they entirely occupy, except for certain relatively unimportant basic and acid intrusives. Microscopic study has shown that these rocks are at times fully developed hornblende schists, and again glossy kinds, in which chlorite is so important an ingredient as to warrant our calling them chlorite schists. In other places again they are more massive, and present more or less distinctly the appearance of fine-grained basic eruptives; but the bulk of these areas is composed of nondescript fine-grained greenish schists, which appear to grade into the more massive greenstone-like forms on the one hand, and into the more distinctly developed chloritic and hornblendic schists on the other. As a rule these various schists present no parallel structure other than that which seems referable directly to secondary causes; that is to say, they do not present such banded varieties as would suggest the action of sedimentation during their production. However, such banded varieties do occur in subordinate quantity, presenting then very strikingly regular, rapid alternations of light and dark bands.

Again, here and there in these peculiar areas, in some places with a very considerable development, there occur kinds which present a more or less obscure fragmental appearance, this appearance being generally far more pronounced on a weathered surface than on a fresh one, on which latter the matrix and the parent fragments are apt to look much like one another, either from original similarity in character or from having undergone alterations which have led both fragments and matrix, originally different, to similar results. At times there is a coincidence of occurrence between the banding above referred to and the appearance of the pebble-bearing forms, but so far as my experience goes this is very commonly not the case, the fragmental phases being without any parallel structure other than the general secondary cleavage, which all of these rocks present, the apparent pebbles occurring more commonly in tumultuous assemblages of masses of all sizes.

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As prominent illustrations of such green schist areas, there may be mentioned that which runs directly westward from the shore of Lake Superior at Marquette, Michigan, for a distance of some twenty miles, with a width ranging from two to six miles;[1] those which occur in the Menominee Valley, on the boundary between Wisconsin and Michigan;[2] that of the Gogebic country of western Michigan, in T. 47 N., R. 43 W., and T. 47 N., R. 44 W., where there is a very great development of the fragmental phases;[3] that which has been recently outlined by Dr. W. S. Bayley to the south of the so-called Mesabé Range, and west of the Embarras Lakes, in T. 59 N., R. 15 W., and T. 59 N., R. 16 W., northern Minnesota, where there is again a considerable development of the fragmental forms;[4] and that which lies to the northward of the iron-bearing slates of Vermillion Lake, traversing the island in the northern part of that lake from west to east, and extending thence east and northeast, with an average width of from two to three miles, through townships 62, 63, 64, and 65 N., of ranges 14, 13, 12, 11, 10, and 9 W., in northern Minnesota, to the national boundary line at Carp Lake, whence it extends an unknown distance into Canada. This last-named area, which is the most extended continuous one with which I am acquainted, shows prevalently those kinds of rock which lack the fragmental appearance. Still, fragmental phases here and there present themselves, as, for instance, along the east shore of that island in Vermillion Lake, which lies in the northern part of Sec. 10 and southern part of Sec. 3, T. 62 N., R. 16 W. To these areas may be added also several smaller ones which lie southward and southeastward of the Vermillion Lake iron belt. One of these areas, lying south of Sea Gull Lake and east of Ogishkimanissi Lake, in T. 65 N., R. 5 W., presents an extraordinary development of the obscurely fragmental or brecciated phase. Finally, should be mentioned the large development of similar greenish schists, including also the fragmental or "agglomeratic" phases, which is described as occurring on the Lake of the Woods in the recent report of Mr. A. C. Lawson, of the Canadian Survey.[5]

My first acquaintance with any of these green schist areas was in the summer of 1883, when a number of days were spent in examining the exposures at Twin Falls, Upper Quinnesec Falls and Lower Quinnesec Falls, on the Menominee River, the boundary between Wisconsin and Michigan. The very handsome detailed maps and the descriptions of these exposures by Maj. T. B. Brooks[6] had already been published and

[1] See map of T. B. Brooks, Geol. Survey Michigan, Atlas, Pl. III; map by C. Rominger, accompanying Geol. Survey Michigan, Vol. 4, 1881; Pl. I of the present volume.

[2] See map by T. B. Brooks and C. E. Wright, Pl. 28 of the atlas to the Geology of Wisconsin; map by C. E. Wright, Pl. 30 of the same atlas; map of the Menominee region, by C. Rominger, Geol. Survey Michigan, Vol. 4, 1881, Pl. 2.

[3] See maps by R. D. Irving and C. R. Van Hise, accompanying a memoir on the Penokee-Gogebic iron region, Mon. U. S. Geol. Survey, No. 18.

[4] See map by R. D. Irving, Pl. XLI, of the Seventh Ann. Rept. U. S. Geol. Survey.

[5] See Geol. Nat. Hist. Survey Canada, Ann. Rep. (new series) Vol. 1, 1885, pp. 41-46 cc; also map accompanying same.

[6] Geol. Wisconsin, vol. 3, 1880.

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were used on the ground. These maps represent the exposures at the several points named as composed of a series of very regular alternations of various schistose and massive rocks, the conclusion being reached with regard to them by Brooks that they form in all a regular series of layers originally of sedimentary origin, the present lack of fragmental appearance being taken as the result of metamorphism. To me it seemed at that time that the regularity of the alternations was far less than one would think to be the case from Brooks's maps, and that all of the several phases, schistose and non-schistose, were rather variations of one great mass of material, whose original structure was massive rather than schistose. This impression was gathered from the way in which the several phases graded into one another, and from the non-continuity in the direction of the strike of the schistose kinds, single schist beds displayed on one side of the stream being often absent where their continuations should lie on the opposite side of the stream. The impression was strengthened by the lack of regularity in the direction of the schist planes, and by the striking way in which schist bands inclose vaguely outlined areas of non-schistose massive rocks. The same conclusion as to the inseparable nature of all of these rocks had already been reached and published by Rominger,[1] though he appears to have looked upon the parallel or schistose structure as representing an original condition of the rocks, all of which he seems to consider of sedimentary origin; while the impression made on me was just the opposite, namely, that the schistosity is of a secondary nature, and the original structure of the rock a massive one. In order to test this question, a large collection of specimens, with quite full notes, was made at the time. In the next year, however, before the thin sections made from these specimens could be examined, the entire collection was destroyed by fire, and my work in other directions having become pressing, it was decided to put the study of this question in the hands of Prof. George H. Williams, of the John Hopkins University, whose qualifications for investigations in microscopic petrography, such as this would mainly be, are well known to be of the first order. In the summer of 1885, therefore, Professor Williams made, at my request, a reexamination of all of these points in the Menominee valley, going into far greater detail in the field study than any one had done before, and collecting on a very large scale. During the summer of 1886, Professor Williams was asked to extend his field examinations into the Marquette greenschist area, and here similar detailed studies and large collections were made. The present publication is the result of Professor Williams's work, which has included the detailed examination of about 400 thin sections made from the specimens gathered.

While Professor Williams's investigations have been going on, the various other green schist areas named, so far as they lie within the

[1] Geol. Survey Michigan, vol. 4, 1881, p. 214.

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boundary of the United States, have been examined in considerable detail, large collections and extensive field-notes having been gathered by Prof. Van Hise, Messrs. W. N. Merriam and W. S. Bayley, and myself. These additional collections are now quite thoroughly sectioned, and it is hoped soon to study them in detail, and to offer a second contribution to our knowledge of this important class of rocks. The present publication, however, deals only with the Marquette and Menominee areas.

Prof. Williams's investigations having been directed especially to a microscopic study of these peculiar greenschists, with the object of ascertaining whether such study would throw any light upon their original condition; it does not come within the province of his memoir to discuss the geologic relations of the green schist masses as wholes. Nevertheless, it is almost unavoidable that some reference should be made in this volume to these geological relations, and, since there has been a good deal of difference of opinion as to them among the several geologists who have written upon the Menominee and Marquette areas, it seems necessary to explain briefly the different views that have been advanced, including the conclusions to which my own studies have thus far led me, though without attempting any general discussion of the subject for the whole Lake Superior region. Such a discussion it is designed to leave until exhaustive microscopic studies, like that of Professor Williams here presented, shall have been extended over the other areas of similar rocks above named. We shall then be in possession not only of all available structural facts with regard to these peculiar rocks, but also of all that the most refined methods of study can give us with regard to their internal texture and mineralogical composition.

The map (Pl. I) shows, in a general way, the distribution of the different kinds of rocks in the vicinity of Marquette. In preparing this map, those by Brooks and Rominger, read in the light of my own studies in this region, have been used. It should be said that a detailed map of the Marquette district has not been attempted by the U. S. Geological Survey as yet, partly because other more pressing work was in progress, and partly because without a thoroughly accurate topographical basis for such a map it has not been thought that much advance could be made upon the several maps heretofore constructed. It is proposed, however, to begin such topographical survey immediately, and upon the basis thus prepared, to place everything exactly as it is seen, and, making use of all the latest mining developments, to attempt to work out accurately and in detail the structure of the region in such a fashion that what is inferred may be easily separated from what is actually known.

Upon the present map the large area colored for greenstone schists is the one which came particularly under Professor Williams's investigations. Northward this area is limited, in the eastern portion, by a great spread of granitic and gneissic rocks. The line of demarkation between the schists and the granites, however, is not a sharp one, since the

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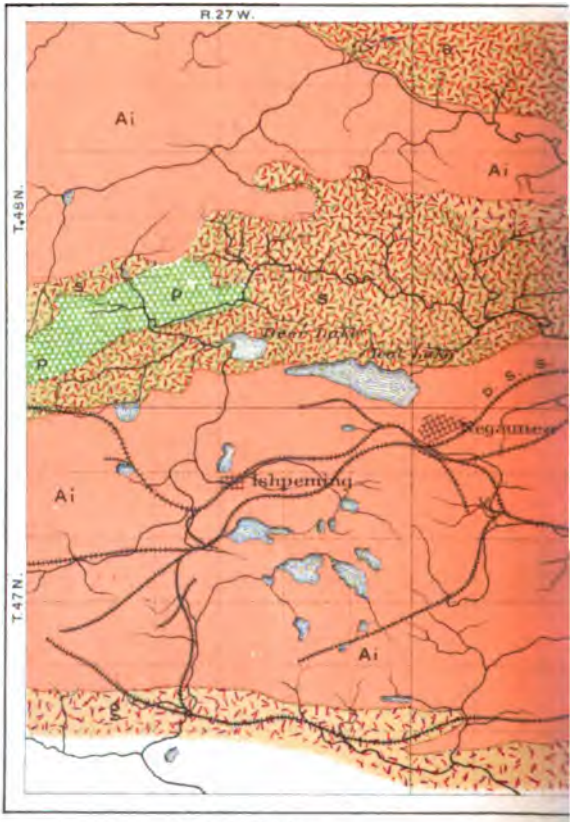

ARCHEAN.

Granite and Gneiss. Greenstone Schists.

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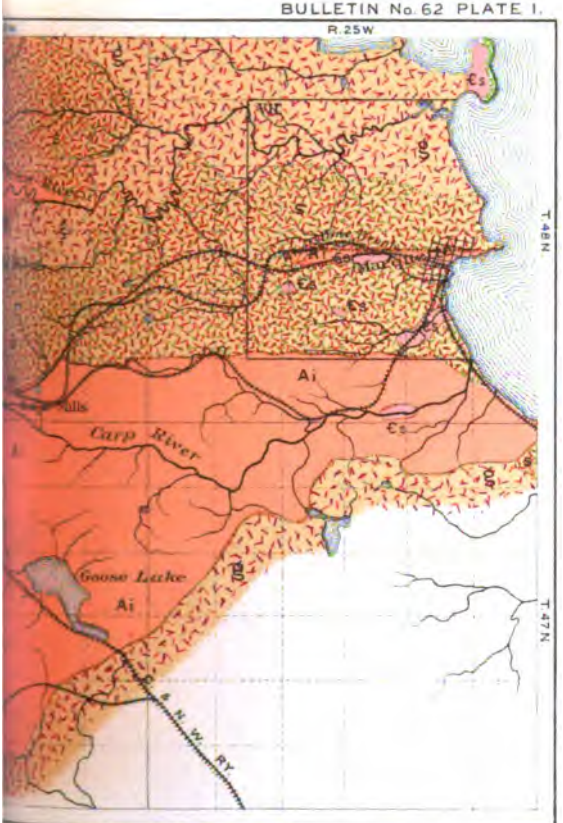
BULLETIN No. 62 PLATE I.



NOWN. ALGONKIAN. CAMBRIAN.

idotite. Iron Bearing Series. Lake Superior S.S.

(Detritals, Limestones and Ferruginous Schists, with interbedded Greenstones.)

Ai Cs

OF THE MARQUETTE REGION.

by T.B.Brooks and C.Rominger.

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two seem to mingle more or less confusedly on each side of the somewhat arbitrary line indicated upon the map. Southward of this greenstone-schist area, and again dovetailing into it on the north, are belts of country occupied mainly by detrital rocks, such as quartzites and various fragmental slates; with these, however, are large bodies of crystalline limestone and several phases of ferruginous schist, all of which have in common an entire lack of anything like a fragmental texture. In addition to these rocks these areas include also sheets of diabasic greenstone, which are interbedded with the detritals and ferruginous schists alluded to. On the south of the southernmost of these detrital areas, in which are included all the well known iron mines of the Marquette region, is again a large area of granitic and gneissic rocks.

The greenstone schists are affected generally by a vertical or nearly vertical cleavage structure, to which the occasional banding of the rock, suggestive of a sedimentary origin, is also parallel. The layers of rock of which the detrital areas are composed are affected partly by a similar cleavage structure, but, on the whole, far less markedly so, while the bedding of these rocks is as a rule very distinct, and indicates a more or less open or gentle bowing of the layers, the dips being at times southward and again northward, and usually at a much lower angle than is the cleavage structure of the greenstone schists. At times, however, particularly in the easternmost portion of the southern of these two belts, the inclinations of the detrital rocks are much higher, and then-bedding and cleavage structure approach to parallelism with each other, and with the cleavage structure of the greenstone schists further north. While folded back and forth, these detrital areas show for the most part an evident general synclinal structure; that is to say, the layers of rock of which they are composed, as they appear along the edges of these areas, dip inward towards their middle portions. Thus the greenstone schists seem plainly to rise from beneath the higher detrital layers. As to the inferior position of these greenstone schists to the detrital iron-bearing rocks, all geologists who have examined this region would probably agree; at all events all those who have expressed themselves with regard to the matter seem to have no hesitation concerning it.

Foster and Whitney, whose classical work[1] gives the first comprehensive account of the geology of this region, do not appear to have separated the greenstone schists from the other stratiform rocks in such a fashion as to indicate their exact stratigraphical relations. All of these stratiform rocks they appear to have looked upon as constituting one great series, whose crumpled condition they attributed to the subsequent eruption of the granite masses on either side of the single trough, which they regarded the stratiform rocks as occupying.[2] They

[1] Report of the geology of the Lake Superior land district, by J. W. Foster and J. D. Whitney, pt. 2. The Iron Region, Washington, 1851.

[2] Ibid., p. 41, Fig. 5.

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appear, however, to refer especially to the greenstone schists in the following:

Many of the slates appear to be composed of pulverulent greenstone, as though they might originally have been ejected as an ash, and subsequently deposited as a sediment, and pass by imperceptible gradations, from a highly fissile to a highly compact state. * * * The slates are composed essentially of the same ingredients as the trappean rocks with which they are associated, and the main difference between them may be that the one was the product of salses, ejected in the form of mud, while the other was the product of volcanoes, ejected in molten streams.[1]

They appear also to refer especially to the greenstone schists when they speak of the stratiform series as exhibiting greater alteration in the vicinity of the masses of eruptive granite, than at distances from these masses.[2]

J. P. Kimball, who wrote in 1864,[3] considered the granitic and gneissic masses on either side of the belt of stratiform rocks, as corresponding to the Laurentian series of Canada, while he parallelized the whole of the stratiform succession with the Huronian series of the north shore of Lake Huron, thus making the granitic and gneissic rocks the older basement upon which all of the stratiform Huronian was subsequently spread, wholly by aqueous agencies. None of the various rocks which Foster and Whitney looked upon as eruptive, are thought by Kimball to have had that origin, even the various greenstones being taken to be metamorphic sedimentary material. In the case below Kimball appears to refer particularly to the greenstone schists, which form our present subject, and which, it thus appears, he looked upon as the basement member of the Huronian succession. He says:[4]

The gneiss which marks the boundary of the granite belts, and accordingly characterizes the top of the Laurentian series in this region, the same as it is elsewhere represented, is succeeded by dark colored hornblendic schists, which consequently represent the base of the Azoic or Huronian series. These schists are followed by a series of augitic rocks and schists, interstratified with magnesian hydrous rocks and slates, the two kinds of rocks being represented on the one hand by hypersthene, pyroxene, and bedded diorite passing into dioritic slates, and on the other by talcose and chloritic schists. The former character of rocks prevails to such an extent as to impart to the lower members of the Huronian series a distinctive augitic aspect. The several rocks composing this augitic zone are commonly of a greenish color, and vary in this respect chiefly as to shade, resembling in this particular the Lower Slate Conglomerate, which marks the base of the series in Canada, and from which they seem to differ only in the absence of pebbles and bowlders from the subjacent Laurentian rocks, which there form a distinguishing feature.[5]

[1] Report of the geology of the Lake Superior land district, by J. W. Foster and J. D. Whitney, pt. 2. The Iron Region, Washington, 1851, pp. 16, 17.

[2] Ibid., p. 14.

[3] Am. Jour. Sci., 2d series, vol. 39, 1865, pp. 290–303.

[4] Ibid., p. 294.

[5] This supposed similarity of the greenstone schists of Marquette to the Lower Slate Conglomerate of Lake Huron is not borne out at all by later microscopic and field studies. Indeed, the two have nothing whatever in common, unless the occasional greenish color of the Lake Huron rocks be taken to indicate such a resemblance. The Lower Slate Conglomerate of Lake Huron, with its granitic and gneissic pebbles, proves to be a most completely detrital and plainly water-formed mass composed chiefly of fragments of quartz and feldspar, with the alteration products of the latter, the whole cemented by a silicious paste. This statement is made only after a careful examination of the Lake Huron region, and after the study of a very large number of thin sections from Logan's so-called Lower Slate Conglomerate.

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T. B. Brooks, upon his detailed map of the Marquette district[1] leaves blank the larger part of the area occupied by the greenstone schists which now especially concern us, indicating here and there upon it, however, the occurrence of belts of "diorite" and of "chloritic and dioritic schists." All of these rocks he evidently regards as belonging conformably beneath the detrital quartzites and slates which form his division No. V, of the iron-bearing series, which division appears in a bold ridge along the northern edge of the southern of the two detrital areas indicated on the outline map herewith. The diorites Brooks classes lithologically with the greenstones interstratified with the detrital rocks themselves, though apparently looking upon them as belonging to much lower layers in the succession. In this lithological correlation, as will be seen in the sequel, Brooks was largely correct, since the diorites of the greenstone schist area prove to be diabasic greenstones in dike form, and to be entirely similar lithologically to the interbedded greenstones of the detrital or iron-bearing areas, with which they are also presumably wholly contemporaneous. All of these rocks, both massive and schistose, Brooks plainly regarded as metamorphosed water-formed sediments.

Wadsworth, writing in 1880,[2] advocates in the main the views presented by Foster and Whitney, as will be seen by the following quotation:

> The general structure of the country would seem to be as follows: The schists, sandstones, etc., having been laid down in the usual way, were then disturbed by the eruption of the jasper and ore; this formed the knobs of jasper, the banding belonging to the fluidal structure, and not to sedimentation. Besides occurring in bosses, the jasper was spread out in sheets, and intruded through the rock in wedge-shaped masses, sheets, and dikes. Much of the original rock still remained horizontal, and new sedimentary deposits continued to be formed out of the jasper and the other rocks. Next came the eruption of "diorite," which completed most of the local folding and tilting of the strata. Finally, the granite eruption took place on both sides of the "Huronian," uplifting and contorting the strata near it, and perhaps laterally compressing the inclosed iron-bearing rocks.[3]

Dr. Wadsworth does not appear to express any particular opinion as to the stratigraphical position of the greenstone schists of the area now especially under consideration, speaking of them only in connection with all the rest of the stratiform rocks of the region as older than the adjacent granite areas. The greater part of these greenstone schists he would seem to have looked upon as certainly sedimentary,[4] since he records a number of observations going to show that there is no gradation between them and certain dike-like masses occurring with them, using these observations in opposition to the ideas expressed by some of his predecessors to the effect that inasmuch as the massive rocks and

[1] Geol. Survey, Michigan, 1873, vol. 1, Atlas pl. 3. See also pp. 99-104, same vol.

[2] Notes on the Geology of the Iron and Copper Districts of Lake Superior. By M. E. Wadsworth Bull. Mus. Comp. Zool. Harvard College, Whole Series, vol. 7 (Geol. Series, vol. 1 No. 1).

[3] Ibid., p. 75.

[4] Ibid., p. 37.

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the schists grade into one another, the former are of sedimentary origin as well as the latter. That there are genuine dikes intersecting these schists and having no gradations into them, Professor Williams's observations recorded in this volume, as well as those by Rominger and others, make very plain, although even in the case of these genuine later dikes there are at times partially schistose forms produced apparently by secondary dynamic agencies. On the other hand, it will be seen from Professor Williams's descriptions that there are other massive forms among these greenstone schists which do present every possible gradation into the schists themselves, and must, therefore, be believed to have had a common origin with them.

Rominger, in his account of the geology of the Marquette region, published in 1881,[1] describes very fully the greenstone-schist area which Professor Williams has studied. Rominger's mapping of this area has essentially been followed upon the small sketch-map accompanying the present volume. The rocks of this area he describes under the general head of the "dioritic group," which group he looks upon as forming the basement member of the Huronian series within which he would include all the stratiform rocks of the region, considering it as placed conformably beneath the detrital strata. The origin of the structure of these greenstone schists he looks upon as having been a secondary one, although he recognizes distinctly their intrusion by later genuinely eruptive dikes. Inasmuch as in its more northern portion the greenstone-schist area presents numerous bosses and veins of granite, he considers these as proving the more recent origin of the great granite masses lying both to the north and south of all stratiform rocks, thus returning, as did Wadsworth before him, to the early expressed view of Foster and Whitney, with whom he agrees also in considering that the crumpling of all of the stratiform rocks, greenstone schists and detritals as well, has been accomplished by the protrusion of the later granite masses on either side. In the same volume, and upon his map, Dr. Rominger indicates numerous small areas of massive and schistose greenstones as occurring in the vicinity of Negaunee and Ishpeming, within the district represented on the outline map herewith, as occupied entirely by the detrital iron-bearing series. These masses he regards as forming portions of his dioritic group, although at the same time recognizing distinctly the fact that they occur at various horizons among the detritals, which he looks upon as lying wholly above the main mass of his dioritic rocks. This anomalous arrangement he explains by representing that the dioritic group, inasmuch as it lies at the base of the entire stratiform series, comes directly into contact with the granite protrusions, whose metamorphosing influence was so great as to cause the fusion of a portion of these basement layers. These fused portions, then, he imagines to have intruded themselves in various shapes among the higher detrital layers.[2] This view, how-

[1] Geol. Survey Michigan, 1881, vol. 4, with map of Marquette region.
[2] Ibid., pp. 22–39, particularly pp. 37, 38.

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ever, Dr. Rominger subsequently abandoned, as will appear from the following quotation from the manuscript of his last and yet unpublished report:[1]

As from the massive form of the diorites a gradation exists into the schistose condition, and as schistose structure formerly appeared to me a positive proof of a former sedimentary origin, I resorted in my previous report, in order to explain the similarity in the composition of the schists with the massive diorites, to the hypothesis of a secondary fusion of the lower beds of sediments nearest to the focus of central heat, and subsequent injection of the fused part into the folds and fissures of the remainder of the strata, simultaneously also the molten mass to have been forced into the fissures and crevices of the adjoining granite. I have since lost much of my faith in this supposition, since I have convinced myself that schistose structure is not necessarily the result of aqueous sedimentation, but that cooling eruptive masses under circumstances can assume a schistose form. * * * I am inclined to suppose that these schists so intimately associated with massive diorite beds are a product of their decomposition, under circumstances favoring the schistose arrangement of the molecules, or, to speak in more definite terms, are a modified form of these eruptive masses, and do not refer to former sedimentary deposits.

My examinations of the Marquette region, made at different times in the summers of 1883, 1886, and 1887, have served to convince me thus far of the correctness of the views of most of the geologists who have examined the region with regard to the inferior position of the rocks of the greenstone-schist area to the remainder of the stratiform rocks. They have also served to impress me strongly with the probable correctness of the view which would make at least some granitic rocks subsequent in point of time to the greenstone schists themselves, since the latter are so intricately penetrated by granitic bosses and dikes in their more northern portions.

I have also seen enough to make me confident that the dike masses which cut the greenstone schists of this area are of wholly subsequent date to the schists, and indeed are equivalent in point of time to those intruded sheets and masses which lie within the overlying detrital iron-bearing series. On the other hand, I have seen some reason to suspect that nearly all previous geologists have been mistaken in considering the rocks of the greenstone-schist area as belonging within the same great geological period as that which holds the remainder of the stratiform rocks of the region. In other words, it thus far appears to me that there is good reason to believe that these greenstone schists along with the granites, gneisses, etc., form a portion of the basement upon which the overlying detrital iron-bearing series was once horizontally and unconformably spread. That they do not constitute the conformably underlying basement beds of that series is suggested by a glance at the map (Pl. I), from which it will be seen that they do not everywhere appear between the granite areas and the detrital rocks themselves, the granite at times coming in contact with them, and again with the higher stratiform horizons. But this anomalous arrangement

[1] Geological Report on the Upper Peninsular of Michigan, exhibiting the progress of the work from 1881 to 1884.

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might possibly be explained by the eruptive nature of the granite, which, since eruptive, would come up indifferently at any horizon of the rocks intruded by it. However, that the granite is not newer than those stratified rocks which overlie the greenstone schists there appears very excellent proof. At a number of points where the detrital beds, which form the basement members of the iron-bearing series proper, come in contact with the granite, they contain its debris in a very notable fashion, while they are entirely devoid of granitic veins, such as occur where the greenstone schists come into contact with the granite. If, then, the granites are of one general age, it appears manifest that they are newer than the greenstone schists, but older than the overlying strata. Moreover, there are several points on the contact line between the detrital rocks of the iron-bearing series and the underlying greenstone schists, where a conglomerate is to be seen, in which are included not only numerous granitic fragments, but also large sized pieces of the greenstone schists themselves.

Since the occurrence of these basal conglomerates is a matter of so important a bearing on the geologic structure of this region, it is desirable that the points of their occurrence should be briefly indicated here. Beginning with the south side of the main, or southern area of the iron-bearing series, indicated on the accompanying sketch map, it may be noted in the first place that at several points along the contact line in Secs. 1, 2, 3, 4, and 5, T. 47 N., R. 25 W., the basal quartzite of the detrital series, which is in general made up almost completely of quartz fragments cemented by a siliceous matrix, takes on a peculiar character, containing at times a large quantity of pinkish orthoclase, along with a good deal of sericitic mica. This peculiar rock was regarded by Dr. Rominger as having been altered from the quartzite by its contact with the more recently erupted granite. A study of the thin sections, however, reveals the completely fragmental nature, not merely of the quartz, but of the feldspar pieces, while the sericitic ingredient appears to have arisen from an immediate alteration of the feldspar fragments. These feldspathic fragments, as also the quartz mingled with them, are of the kinds characteristic of granite, and, moreover, are entirely identical with those occurring in the granite with which this peculiar rock is in contact. Southwest of Goose Lake, however, in Secs. 21 and 22, T. 47, R. 26 W., there are much more obvious occurrences of granitic débris. In the lower detritals of the iron-bearing series near the southwest quarter of section 22 may be seen layers of fragmental quartz slate holding seams of granitic pebbles; while in the southeast quarter of the same section contacts are seen between the fragmental quartzite and masses of the granite, the quartzite at the contact being crowded with bowlders and fragmental material of all sizes derived from the granite. It is not evident whether the granitic masses here seen are brought to view by a fold of the strata, or are directly connected at surface with the main granitic mass lying to the southeast of them, the

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exact outlines of the areas occupied by different rocks in this vicinity having never been traced. These occurrences were noted by Dr. Rominger,[1] who also describes similar ones as obtaining in the southwestern portion of the same township. It should also be said that, at numerous points along this line, the quartzite contains pebbly beds in which the pebbles are of a quartzite whose microscopic features prove to be those so well known as characteristic of the quartz of granite.

Turning now to the northern line of the same area we may note first the conglomerate to be seen on the side of the so-called State Road, running west from Marquette at a point near the west line of the SW. ¼ of the SE. ¼ sec. 29, T. 48 N., R. 25 W. This is exactly on the line between the greenstone-schist area and the area occupied by the detrital rocks, which just here are thinly banded slates, standing vertical or even overturned slightly so as to dip to the northward and to lie in general conformity to the cleavage of the greenstone schists immediately north. These slates, whose lithological character is one very commonly met with at the base of the iron-bearing series in many different portions of the Lake Superior region, are proved by the thin sections to be quite beyond question water-formed detritals and at the same time to present a most striking contrast with the hornblendic and chloritic greenstone schists lying immediately north of them. This contrast, however, though very distinct in the thin section, is by no means so pronounced in the hand-specimens which, though one sees that they are of two different natures, might nevertheless be readily taken to be all of the same origin. At the point indicated the fragmental slates become crowded with large and small fragments of granite, quartz, and green schist, the quartz pebbles usually being of rather small size, while those of granite, which are the most numerous, are well rounded and reach as much as two feet in diameter. The green schist pebbles, on the other hand, are not so plentiful, but are still abundant and of all sizes, from the smallest particles up to pieces a foot across. The larger schist pieces are somewhat rounded, but in the main they are all far less so than the fragments of granite and quartz. The thin sections cut from the matrix of the rock show that it is completely of a detrital nature. On the north side of Teal Lake, at both eastern and western extremities, are found other conglomerates, in one case holding only quartz pebbles, and in the other case pebbles not only of quartz, but of greenish schists as well.

Turning our attention now to the northern one of the two detrital areas indicated on the sketch-map herewith (Pl. I), I may note the occurrence at a number of points along its southern margin of conglomeratic layers of quartzite and sandstone, in which are contained pebbles of white quartz, which pebbles are at times identical in microscopic and macroscopic appearance with the quartz of certain seams in the greenish schists (as, for instance, on the west line of Sec. 20, T. 48 N., R.

[1] Geol. Survey, Michigan, vol. 4, 1881, pp. 62, 63.

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27 W.), or with that of the granite (as, for instance, near the middle of the south half of Sec. 17, T. 48 N., R. 26 W.), against which different rocks the quartzites rest in different places. Near the middle of Sec. 21, T. 48 N., R. 27 W., the quartzite, resting here against certain agglomeratic green schists, contains not only fragments of quartz like that of numerous seams in the green schists, but also pieces of the green schists themselves, which in some cases are several inches in diameter.

But the most striking occurrences of basal conglomerates upon the edges of this area of detrital rocks are those to be met with in the northern and western portions of T. 49 N., R. 28 W. One of these places, to which my attention was first drawn by Mr. C. E. Wright, the state geologist of Michigan, is on the northwestern shore of Silver Lake, in the SE. ¼ of the NW. ¼ of Sec. 8. Rising abruptly all along the northern side of this lake is a bold ridge of granite with which are associated several kinds of schistose rocks, very prominent among which is a fine-grained green schist entirely analogous in general appearance to the greenstone schists which form the special subject of this paper. At the particular point to which attention is now directed, this granite protrudes in places into the lake in low, shelving ledges, facing which, and lying within the cracks of which, is a black cherty slate. Following the shore along to the southwestward from these exposures, the cherty slate is found more largely developed, occupying a large hollow in the surface of the granite, and becoming crowded with its fragments of all sizes, from a fine detritus up to pieces two feet in length. These fragments, though prevailingly subangular to angular in outline, generally present some evidence of water-wearing. Many of them are quite gneissoid in structure, while others are more granitic, two principal phases being thus presented. The thin sections made from the specimens selected on the ground as characterizing these two phases of pebbles, and also the granitic and gneissoid phases of the granite against which the conglomerate rests, show the entire indentity of the fragments and the massive granite. In addition to the granite fragments are rarer ones of white quartz, these occasionally being of some size, and others of a greenish schist entirely analogous to that green schist which occurs here in situ along with the granite. The matrix of this conglomerate is a dark gray to nearly black, carbonaceous, cherty slate, which in the thin section shows a predominating quantity of a cherty, chemically deposited silica, with which are mingled varying proportions of fragmental material, this fragmental material being composed of pieces of quartz and feldspar, and again, when the pieces become coarser, of a granite in which these same minerals are attached to each other. At times, as is so commonly the case among the cherty rocks of the iron-bearing series generally, throughout the Lake Superior region, there is a brecciated condition in this slaty matrix itself; that is to say, irregular, angular pieces of the carbonaceous cherty material are cemented together by a matrix of the same substance. Quite similar occurrences

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are met with near the center of Sec. 19, of the same township, where black cherty slate and quartzite lie upon the east and south flanks of a bold hill of granite; both slate and quartzite, and particularly the latter, being crowded with fragments of the granite, which range from small pebbles up to pieces a foot or more in diameter, the smaller sized pebbles being usually quite well rounded, while the larger fragments are subangular to angular.

Such occurrences as these, when considered in connection with the manner in which the granite penetrates the greenish schists and is involved with them, seem to render necessary the belief that, while it is plainly younger than the green schists, it is nevertheless greatly older than the overlying detrital rocks; and more than this, that when the latter rocks were spread, the granites and greenstone schists together had already suffered disturbance and deep denudation. It does not appear possible to escape this conclusion by supposing that, since granite and greenstone schists are eruptives, they may have furnished fragments to almost contemporaneous sedimentary deposits; for, in the first place, both the greenstone schists and the gneissoid granite must have received their schistosity before yielding the fragments. Moreover, whatever may have been the depth at which the schistose rocks were first formed, the granitic masses which intruded them, according to all the later developments and doctrines of petrography, must have been crystalized in depth, and must therefore have had removed from over them great masses of materials before yielding fragments to wave action. In this connection attention should be drawn to the fact that there are evidently granitic rocks of two different ages in the great granitic areas of the Marquette region; because dikes of a fine grained, reddish granite are frequently met with cutting the other granite, which may be either gneissoid or not. These later granites, which appear to be of relatively small extent compared with the main mass, may perhaps have been even later in time of formation than the detrital rocks themselves. It seems probable that to these later granitic eruptions we should refer certain rare quartz-porphyry dikes, and such very rare granitic dikes as that which is seen near Metropolitan, in the Felch Mountain district, intersecting a ferruginous schist of the iron-bearing series itself.

On the whole, then, accepting Prof. Williams's conclusions as to the surface origin of most of the greenstone schists of the Marquette region, I should suppose that, after the accumulation of these rocks to the thickness of several thousand feet, they were intruded by granitic bosses. These bosses perhaps may have been merely softened portions of the underlying gneissic basement, which indeed may be represented in an unaltered condition in portions of the granitic areas themselves, for all that has yet been determined to the contrary. Subsequent mountain-making movements brought about the folding and alteration of these enormous sheets of eruptive material, now represented by

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the greenstone schists. Following this was the great denudation which brought to light the previously buried granitic masses. This erosion was followed in turn by the accumulation in the usual horizontal position of the iron-bearing detrital series, whose folding and erosion were still later processes. And yet this folding and erosion all preceded the deposition of the horizontal Cambrian sandstones of the region.

The entire similarity which is shown by Prof. Williams to obtain between the great dikes of diabasic greenstone which traverse the greenstone schist area, and the sheets of eruptive greenstone which are included within the iron-bearing series, furnishes a further confirmation of these conclusions. For the latter greenstones are in large measure directly interstratified with the sedimentary layers of the iron-bearing series, following the bending of its layers; so that even if these greenstones are in the nature of intruded sheets, it seems necessary to believe that their intrusion took place before the folding of the iron-bearing series. Now, the corresponding dikes in the greenstone-schist area were evidently intruded subsequent to the production of the schistosity of the intruded rocks. If, then, these are facts, the time when the iron-bearing series was folded was very much subsequent to that time at which the greenstone schists received their schistosity. It has been mentioned that the schistose structure of these greenstones at times corresponds with the bedding structure of the iron-bearing series. But quite frequently there is no such correspondence, the beds of the latter series being noticeably at relatively lower angles when compared with the vertical schistose structures of the greenstone schists themselves.

Such correspondence in some places and lack of correspondence in others are easily enough explicable upon the views that I have advanced. However, there is good reason to think that at the time of the folding of the iron-bearing series, the greenstone schists received a second squeezing, which developed further alterations and further schistosity. The later dikes just alluded to as penetrating the green schists are at times rendered somewhat schistose, though far less markedly so than are the rocks which they intrude. The same is true with the greenstones that are intercalated in the iron-bearing series, where somewhat schistose phases are found. The structure of these last-named schistose phases, as also the occasional slaty cleavage seen in the detrital layers of the iron-bearing series, where it is very strongly folded, correspond in general direction, as would be expected, with the schistose structure of the greenstone-schist areas.

The geology of that portion of the Menominee region which has been especially under study in the present connection, is indicated by the outline map, Plate II. Here, again, we find a series of detrital iron-bearing rocks, lying between great areas of granite and gneiss. The iron-bearing rocks are generally quite closely like those of the Mar-

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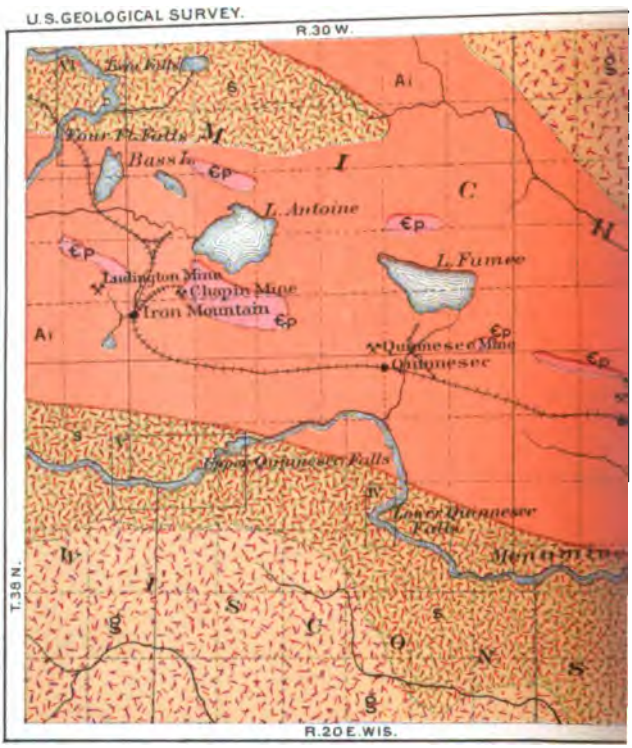

ARCHEAN.

Granite and Gneiss. Greenstone Schists.

OUTLINE GEOLOGICAL MAP O

Compiled by R.D. Irving from maps by T.B. Brooks.

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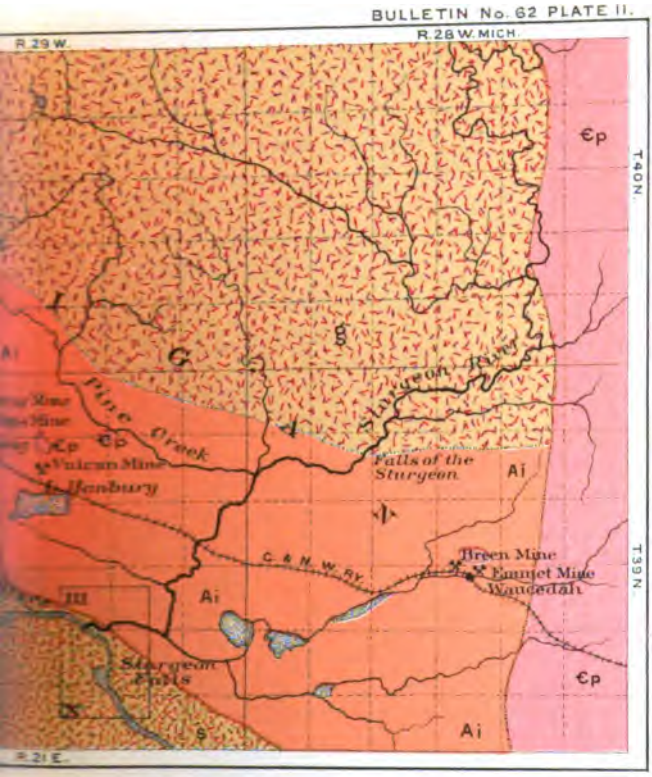

ALGONKIAN.

Iron Bearing Series.
(Quartzites, Limestones & Ferruginous Schists.)

Ai

CAMBRIAN.

Potsdam Sandstone.

Ep

THE MENOMINEE IRON REGION.

Wright and C. Rominger and from original observations.

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quette region, the only important differences being the very great rarity of greenstone intrusions, and the very much more closely crumpled condition which the rocks here present. In the same region are two belts of greenstone schists closely analogous in general appearance with those of the Marquette region. The southern one of these borders for a long distance the southern granite area, separating the granite from the detrital rocks further north. The inclination of the schistosity of the greenstone schists is almost vertical, there being generally a slight southern departure from verticality. Very high southern dips, often approaching verticality, also prevail among the layers of the detrital succession itself, although here frequently occur reverse dips to the northward, often at a flatter angle.

The first geologists who appear to have noted the Menominee rocks are Foster and Whitney and Charles Whittlesey, as quoted in Foster and Whitney's work.[1] By these writers all of the Menominee stratiform rocks, so far as they were encountered in the rapid trips by canoes, which were at that time the only means of traversing the country, were classed together under the general name of Azoic slates. However, the exposures of greenstone schists, which are met with at Twin Falls, Upper (Big) and Lower (Little) Quinnesec Falls and Sturgeon Falls, appear to be directly referred to as intercalations of "Azoic slates and traps;" so that, while no opinion was expressed as to their stratigraphic relations to the other rocks of the region—beyond what is indicated in general statements as to the greater recency of all the granitic masses of the region as compared with the schistose and slaty rocks—it appears plain that these geologists looked upon the rocks now included under the term of greenstone schists as partly eruptive and partly sedimentary.

The same conclusion as to the origin of these rocks appears to have been reached by Credner, who published an account of this region in 1869,[2] after having been some time on the ground as an assistant to Prof. R. Pumpelly in a private economic examination of the lands of the Lake Superior Ship Canal Company. On account of the slight departure from verticality towards the south; on account of the schistose structure of the rocks exposed at the several falls of the Menominee, which rocks he describes under the general term of "Dioritic Series' and "Talcky Clay Slate," and because of the prevalence of similar southern dips among the detrital iron-bearing rocks farther north, Credner considers the former rocks as constituting the highest portion of the entire succession of the region. That there existed to the south of these rocks another mass of granite does not appear to have been realized by Credner.

T. B. Brooks, who followed Credner in the Menominee region and

[1] Geological Survey of the Lake Superior Land District, vol. 2, pp. 24–31. See also general section of the Lake Superior region in atlas to the same volume.

[2] Die vorsilurischen Gebilde der oberen Halbinsel von Michigan in Nord-Amerika. Zeitschr. Deutsch. geol. Gesell., Berlin, 1869, vol. 21, pp. 516–554.

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who published a brief account in the reports of the Geological Survey of Michigan[1], appears to have agreed with that geologist with regard to the relatively high position in the series of the greenstone schists of the Menominee River. Subsequently the same geologist, assisted by C. E. Wright, was engaged in a more minute examination of this region on the part of the Wisconsin State Geological Survey, publishing a somewhat elaborate report in 1880.[2] In this report very many more facts are given than were ever known before, all exposures seen being very accurately and carefully indicated upon the accompanying maps. This detailed work, however, does not appear to have altered Brooks's opinion as to the relatively high position in the Menominee series of the greenstone schists now especially under consideration, although it appears that he would now correlate them with still higher layers of the Marquette series rather than with those to which he had previously referred them. As to the origin of the greenstone schists, Brooks would seem to have regarded them at first as all sedimentary; at all events when the Michigan report referred to was written.[3] Later, however, he appears to have been disposed to separate from the rest certain diabases as eruptive, thus coming nearly to the same conclusion as that reached by Credner.[4] To convey Brooks's conception of the structure of this region more clearly, there are given here two sections, constructed from general sections given by him upon Plates 27 and 29 of the atlas to the Geology of Wisconsin. The granitic

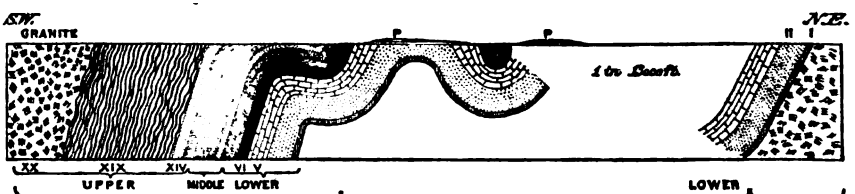

FIG. 1. Hypothetical section of the Menominee region in the vicinity of Quinnesec, according to Brooks; I, Sericitic slates; II, quartzite; V, limestone; VI, the great iron horizon; XIV, quartzite; XV to XIX, greenstone schists, etc.; XX, Huronian granite; P, Potsdam sandstone. Scale 13,000 feet to the inch.

and gneissic rocks to the north Brooks regarded as having formed part of the ancient Laurentian basement upon which all of the slates and schists were subsequently piled. From this northern granite to the granite on the south side of the Menominee he looked upon the entire succession as an ascending one, though admitting certain bowings of the strata. The southern granite, as to whose sedimentary or eruptive origin he appears to have been doubtful, he places as the summit member of the Huronian series. The entire succession he divides into three portions, beginning below or to the north, as follows: Lower Huronian,

[1] Geol. Michigan, vol. 1, 1873, pp. 157-162. See also atlas to the same, Pl. 4.
[2] Geol. Wisconsin, vol. 3, 1880, pp. 430-663; also atlas, Pls. 28-30.
[3] Geol. Michigan, vol. 1, 1873.
[4] Geol. Wisconsin, vol. 3, 1880, p. 521.

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5,200 feet; Middle Huronian, 3,100 feet; Upper Huronian, 10,700 feet; making in all a maximum thickness of 19,000 feet beneath the upper or southern granite. The surface distribution of the uppermost of these three divisions corresponds almost exactly with the areas of greenstone schists indicated upon the outline map herewith (Pl. II). The more north-

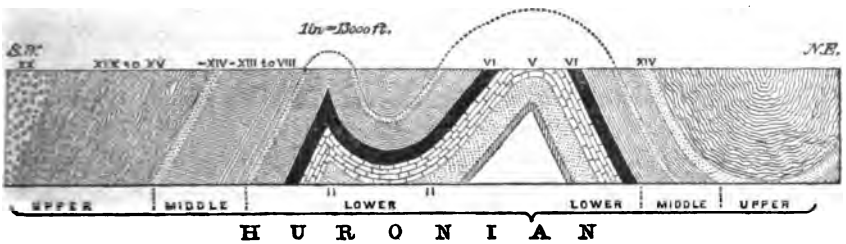

Fig. 2. Hypothetical section of the Menominee region in the vicinity of Twin Falls, according to Brooks. Scale 13,000 feet to the inch. Letters and shadings have the same significations as in Fig. 1.

ern area of greenstone schists, namely, that which is sectioned by the Menominee river at Twin Falls, is made on Brooks's structural sketches to be brought to view by a synclinal depression of the strata. For this view of the structure of the region there never was any other support than the very slight departure from verticality towards the south of the schistose structure of the southern greenstone schists and a prevailing similar inclination in the detrital iron bearing series proper. No contacts of the different kinds of rocks were observed to support Brooks's hypotheses as to the relatively high position of the greenstone schists and southern granite, between which and the other stratiform rocks there is indeed usually a wide belt of country without exposures. On the other hand, the extraordinary similarity of these greenstone schists to those which Brooks regarded as underlying the entire Marquette series appears to have been disregarded, as also was the complete similarity between the northern and southern granites, and again between the contact of the southern granite with the greenstone schists next to it, and the corresponding contact in the Marquette region.

Rominger, who followed Brooks in the Menominee region in 1880 and published an account of his observations in 1881, appears[1] to have realized very vividly the difficulties met with in accepting Brooks's structural hypothesis. He represents all of the greenstone schists of the region as belonging at the base of the entire stratiform series, and as equivalent in position and nature with the similar rocks of the Marquette region. The northern and southern granites Rominger looks upon as the same, and as intrusives of a date later than the accumulation of the entire stratiform succession. As to origin, he evidently looked upon the greenstone schists as altered sedimentaries, assigning the relatively great alteration, which on this view they must be assumed to have undergone, to the action of the later granitic bosses; in which

[1] Geol. Survey Michigan, vol. 4, 1881, pp. 157-241.

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view he fails quite to explain, as he does in the case of the Marquette region, how the southern granite of the Menominee area should have produced so great alterations, while that on the north comes in contact with wholly unaltered detrital rocks, to which moreover, as Brooks had previously shown, it furnishes an abundance of detrital material. Unfortunately, though describing carefully very many exposures not recorded on Brooks's map, Rominger gives no sections indicative of his views as to structure. Just what his ideas were in this respect it is not easy to make out from his descriptions, but it appears evident that with him the greenstone schists lie at the base of the succession; that they are next succeeded in order by those slates which lie about Lake Hanbury; that these are succeeded by the great ore horizon, and this by the great limestone bed of the region with a thickness of a thousand feet and more. Thus he reverses entirely the succession as given by Brooks, and as it appears in nature so far as the limestone and ore belts are concerned. What stratigraphical position Rominger would give to those great masses of quartzite which lie adjacent to the northern granite in Menominee belt I have not been able to understand distinctly from his descriptions. The Twin Falls greenstone schists he would place along with the Quinnesec series at the base of the entire succession, bringing them to the surface by an anticlinal instead of a synclinal fold, such as is resorted to by Brooks. The following paragraphs are quoted from Rominger,[1] as indicative of his views upon these points:

A superposition of the diorite formation on the Lake Hanbury rock series, which adjoins in the whole length of the Menominee valley from the upper Quinnesec Falls to the Sturgeon Falls, asserted by Major Brooks, is not observable; the nearly vertical strata of both formations are even never seen in contact. There is always quite a large covered interval between them. The nearest exposures of the two groups are observable in Sec. 26, T. 39, R. 29, where, in the center of the section, a hill is formed of the vertical ledges of ferrugino-siliceous flagstones and slaty beds representing the Lake Hanbury series, and about two or three hundred steps from these exposures we find on the south side of the road to Menominee small hillocks of diorite. * * *

My reasons for holding the dioritic rocks south of the iron formation as older than the latter are based on the lithological similarity of this formation with the dioritic group of the Marquette district and on the degree of metamorphism exhibited by the two groups, the dioritic and the iron-bearing. In the great succession of strata commencing with the Hanbury slate group and upward we rarely find a bed so much altered that its sedimentary structure is altogether obsolesced, and the majority of the strata shows it very plain, while in the dioritic rocks, considered to be the younger, a stratified structure is also recognizable, but not one of these thousands of feet of ledges exhibits its original sedimentary lamination with any degree of distinctness like the others; they have evidently been transformed under cooperation of heat and partially brought into a plastic condition, which is shown by the extreme corrugation and mode of intermixture of those rock masses, of which effects the other rock groups do not exhibit near as high a degree. It would be very strange, then, if the lowest beds nearest to the focus of the central heat should have been so much less affected by these altering influences than those pretended to be the higher upper strata of the rock crust. One might object: If the diorites are the older beds, why don't we find them just as well developed on the north side of the upheaved beds between the quartzite and the granite? The sandy and conglomeratic nature of

[1] Geol. Survey Michigan, vol. 4, 1881, pp. 208-210.

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many of the strata of the quartzite and iron formation proves them to be shore deposits, while the dioritic group consists only of the finer material of deep sea deposits, which explains the point in question. Moreover, the dioritic rocks are not altogether missing on the north side of the ore-formation, as we can see by the occurrence of the 6-mile-long chain of diorite extending eastward from the Twin Falls. A similar discrepancy between the rocks underlying the ore-formation on the two opposite sides of its exposure is seen in the Negaunee district. On the south margin, at the Cascade and Palmer mines, it rests directly on the granite, while on the northern exposures the diorite underlies it in great thickness.

The equal dip of the strata to the south in these adjoining formations is not necessarily a proof of the younger age of the most southern beds. The whole succession is so near to a vertical position that in many instances it has to be left uncertain which way they dip, but suppose their dip is conformably to the south; the upheaval of the diorites by the eruption of the still more southern granite masses pushing the whole incumbent rock-series north until all tipped over is the hypothesis by which I explain the order in the succession of beds as an inverted one, the seemingly lowest beds being actually the youngest.

In my own studies in the Menominee region, made in the summers of 1883 and 1885, I became early impressed with the close similarity between the greenstone schists of the Menominee River and those which underlie the iron-bearing series of Marquette; with the entire similarity between the rest of the stratiform rocks of the region and those of the Marquette district; with the essential identity in character of the granite areas lying respectively on the northern and southern sides of the Menominee River; with the granitic intrusions met with in the greenstone schists bordering the southern granite, and with the striking contrast between the nature of this contact and that of the northern granite with the detrital rocks which border it to the south. In the latter case the granite, instead of sending intrusions into the rocks which rest against it, has furnished fragments to them, as may be most beautifully seen at the Falls of Sturgeon, Sturgeon River, on the eastern side of Sec. 8, T. 39, R. 28 W., Michigan.[1] These considerations naturally

[1] For previous descriptions of the striking occurrences at the Falls of Sturgeon, Sturgeon River, see Credner in "Die vorsilurischen Gebilde der oberen Halbinsel von Michigan," Zeitschrift der Deutschen geologischen Gesellschaft, vol. 21, 1869, p. 521, et seq.; also T. B. Brooks, in Geol. Wisconsin vol. 3, 1880, pp. 467, 468, and Atlas, Pl. 38; also, see Rominger, Geol. Michigan, vol. 4, p. 192. The granitic fragments at this place occur in a fine-grained slaty rock, in which there is a great deal of sericitic material, which at times gives the slate somewhat the look of a crystalline schist. This fact, along with the slight inclination from the vertical towards the north, and therefore towards the granite, which is so largely exposed farther up the stream, led Credner to include these conglomeratic layers, along with the granite, as Laurentian, the great quartzite mass farther south being taken by him as the basement member of the Huronian. Brooks, however, objects to this conclusion, considering that the conglomerates to be seen at this place are genuinely basal conglomerates, and that they form the lowest portion of the Huronian region. To support this view, Brooks draws attention to the frequent arenaceous nature of the conglomeratic slates; their ripple-marked surfaces; their generally little altered appearance; their parallelism of strike with the admitted Huronian beds farther south, and the lack of parallelism between this strike and such structures as is to be seen in the granitic and gneissic rocks on the north. Rominger's description corresponds with that of Brooks, except that he seems to describe a granitic mass or sheet as occurring interleaved with the conglomerates themselves, a statement for which, in my examinations, I could find no support whatever. Rominger, however, to whom the greater recency of all the granite as compared with all the stratiform rocks was an accepted conclusion, explains the occurrences as he saw them by the singular supposition that "we have here evidently a series of sedimentary beds, deposited on a granitic substratum, which, during the upheaval, became wedged in between the plastic granite mass, tilting and overlapping them locally so as to appear as the lower beds," thus making the same granite yield fragments to the sedimentaries, and subsequently intrude them. It should be said that the examinations of the several geologists were

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led me to the conclusion that the whole structure in this district is similar to that already described as obtaining in the Marquette region, namely, that the granitic masses had intruded themselves in the shape of great bosses into rocks now represented by the greenstone schists, after which followed a protracted period of disturbance and denudation before the deposition of the overlying detrital and iron-bearing rocks of the region. Taking Major Brooks's detailed map of the Menominee district, published in the atlas of the Wisconsin survey, I platted upon it all of the exposures described by Rominger and not mapped by Brooks, which exposures amount in all to a large number. Examining, then, the more important of the exposures of the region, I encountered still others, which were also platted upon the same map. Two sections were then constructed across the district from southwest to northeast, upon which were platted all of these exposures, with their dips; and it should be said that very many new facts in this direction have been developed of late years by mining.

FIG. 3. Hypothetical section of the Menominee region in the vicinity of Quinnesec Valley, according to R. D. Irving. A, basal sericitic quartz slates; B, quartzite; C, limestone; D, iron horizon; E, slates and quartzites; G, granite and Sch., schists of the Laurentian. Scale, 13,000 feet to the inch.

It has thus become evident that a structure such as is indicated in the accompanying Fig. 3 would not only coincide with the recorded facts as well as the sections of Brooks above given, but very much better than those.

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made without the study of thin sections of the slaty rocks here exposed. When examined microscopically, these rocks show their completely fragmental nature, all the alteration that they have undergone having been in the nature of a metasomatic development of mica flakes. Both hand specimens and thin sections of these slates, moreover, show a most striking similarity between them and the slaty rocks which frequently lie at the base of the Penokee series of northern Wisconsin and Michigan, where they are often in contact with granitic rocks, of which they hold fragments. Similar slates are met with in a number of places at the base of the iron-bearing series of the Marquette region. As seen at the Sturgeon Falls, these slates are at times fine grained and thinly laminated, arenaceous and sericitic, and again more closely grained and of a vitreous quartzitic appearance, in which cases the predominating quartz fragments have been cemented together by secondary enlargement. Their entire ack of anything like metamorphism is perfectly plain, even without the examination of the thin section, to any one who has studied many sections of such rocks from the Lake Superior country. The pebbles in these slates are arranged in bands, with intervening less pebbly or non-pebbly portions, which portions are the ones which show particularly the ripple-marked surfaces. The pebbles are in the main of a pinkish granite and gneiss, wholly identical with the mass of granite and gneiss against which they lie, but include also a smaller number of pieces of white quartz and of a fine-grained greenstone or greenstone schist. Entirely similar quartz occurs in seams in the granite close by, as do also masses of greenstone and greenstone schist. Not only these pebbles, but the whole make-up of the finer portion of the rock, make it entirely evident to me that we have here to do with a detritus derived by water action from the granitic and gneissic area immediately to the north. The slight inclination away from the vertical towards the granite which these conglomeratic slates sometimes show is, of course, no argument against their having been deposited upon that granite as a substratum.

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THE GREENSTONE SCHIST AREAS OF THE MENOMINEE AND MARQUETTE DISTRICTS, MICHIGAN.

By GEORGE HUNTINGTON WILLIAMS.

INTRODUCTION.

This memoir is intended as a contribution to the subject of dynamic or regional metamorphism. It contains the results of a careful study, both in the field and in the laboratory, of an extensive series of eruptive rocks, for the most part of basic character. Although the original character of these rocks is still evident, they are to a large extent cleavable, and the production of this secondary feature has been accompanied by more or less extensive chemical and structural alterations.

It is the aim of this paper to trace each of the rock types represented within the areas studied from its least altered to its most altered form, and to discuss what may have been the agencies which produced the changes noticed.

The rocks selected as likely to throw additional light upon the metamorphism of eruptive masses are so-called "greenstones" and "greenstone schists," which, in association with certain more acid types, cover extensive districts on the south shore of Lake Superior, where they lie immediately beneath the iron-bearing strata. Two distinct and sharply defined areas of these rocks were chosen as typical of the whole formation. Particulars regarding their geographical positions and their geological relationships have already been given by Professor Irving in his preliminary note. In the first area, situated on the Menominee River, the eruptive character of the greenstones and greenstone schists is plainly evident; within the second area, near the city of Marquette, the original character of the rocks is much less apparent.

The investigations, the results of which are embodied in this memoir, were first suggested to me in the spring of 1885 by the late Prof. R. D. Irving, while he was in charge of the Lake Superior division of the U. S. Geological Survey. Their aim was to discover, if possible, the origin of the greenstone schists of the Lake Superior region, and at the same time to afford a contribution to our knowledge of the metamorphism of basic eruptive rocks in general. In the latter sense they form a continuation of the writer's earlier studies of the less altered gabbros occurring near Baltimore, Maryland.[1]

[1] Bull. U. S. Geol. Survey, No. 28, 1886.

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Three weeks of the field season of 1885 were spent in the Menominee Valley, and four weeks of 1886 in the neighborhood of Marquette. During this time, with the assistance of Prof. W. S. Bayley, the rocks were examined in the field, and ample material was collected for their laboratory study, which was carried on at the Johns Hopkins University, Baltimore, Maryland, during the winters of 1885–'86 and 1886–'87, at such times as could be spared from regular university duties. The entire investigation has been conducted under the auspices of Professor Irving, for whose uniform kindness and constant readiness to supply every facility for the work I gladly take this opportunity of expressing my sense of deep obligation. My thanks are also due to Maj. T. B. Brooks and to Prof. Raphael Pumpelley for the loan of microscopic sections of the Marquette and Menominee rocks, prepared during the course of the Wisconsin State Geological Survey; and to Mr. Andrew C. Lawson, Ph. D., lately of the Canadian Geological Survey, for the opportunity to make a comparative study of closely allied rocks from the Lake of the Woods and the Rainy Lake regions.

I feel that no especial apology is needed for the constant use throughout this paper of the term "greenstone." An opinion prevails that this word is antiquated and not consistent with the scientific accuracy now obtainable. The very indefiniteness of this designation, however, constitutes its chief value. It is essentially a field term, such as it is not only desirable but absolutely necessary to employ. It is often impossible to state with certainty in the field whether a given basic massive rock is a gabbro, a diabase, or a diorite; indeed, where such masses have undergone extensive metamorphism, as in the regions here studied, even the most careful microscopical and chemical investigation may prove inadequate to disclose what was the original form. Wherever accurate diagnosis was possible, correspondingly definite terms have always been employed; but for use in the field or where the processes of alteration have obscured the original character of the rock beyond recognition, an intentionally indefinite designation is necessary. For such a purpose it is believed that no term is better fitted than the ancient and much abused "greenstone."

For convenient reference the specimen numbers belonging to the collections of the Lake Superior division of the U. S. Geological Survey are here appended.

1. *Menominee Valley*	11000–11196
Sturgeon Falls	11153–11174
Little Quinnesec Falls	11000–11048; 11098–11103
Big Quinnesec Falls	11049–11085
Horse Race	11086–11096; 11182–11196
Four Foot Falls	11142–11152; 11175–11181
Twin Falls	11120–11141
2. *Marquette region*	11610–11864
Marquette area	11610–11734
Negaunee area	11735–11812
Northern area	11813–11864
3. *Agglomerates of Deer Lake*	12023–12058

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The material embodied in the present paper will be arranged in three separate divisions.

1. In chapter one the importance of the service which the microscope is capable of rendering toward the solution of the questions of archæan geology will be indicated and a summary presented of the chief results already obtained by various workers in this field.

2. In chapters two, three, four, and five the observations collected during an extended study of the rocks of the two areas selected will be given in detail.

3. In chapter six a connected discussion of these results will be attempted, and a comparison of them with those reached by other observers, as enumerated in chapter one, will be made.

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CHAPTER I.

PRESENT STATE OF OUR KNOWLEDGE REGARDING THE METAMORPHISM OF ERUPTIVE ROCKS.[1]

VALUE OF THE MICROSCOPE IN THE STUDY OF METAMORPHISM.

In comparison with the results which have been obtained during nearly a century of patient research among sedimentary deposits, the progress thus far made in the domain of archean geology appears small. Theories of the origin of the so-called crystalline schists are almost as numerous as the investigators who have examined them, and yet the more extensive and critical the studies of these rocks become the more obscure and anomalous do they appear. So varied are the facts which Nature presents to the observer in the oldest rocks of the planet that the conviction is soon reached that no single hypothesis or explanation can account for them. It is therefore from no lack of interest attaching to the study of pre-fossiliferous rocks that they have heretofore yielded so little fruit, but rather from the insurmountable difficulties which have stood in the way of their satisfactory investigation. That the study of fossils has made up so large a part of what has been known as geology is the result rather of necessity than of choice. The lack of exact and delicate methods of lithological research has confined the attention of investigators to those formations where lithological characters are of little value on account of the presence of other and more certain guides. The basement underlying all of the fossiliferous rocks has, therefore, remained well-nigh a terra incognita, because there seemed to be no available means of exploring it.

The recent multiplication of refined methods for the investigation of crystalline rocks, however, has opened an almost new field of geological inquiry. The difficult and obscure problems here presented may now be attacked by truly scientific methods. The prophecies which Hermann Vogelsang made in 1867[2] for the new departure in geology have been more than realized within the last twenty years. The almost new science of petrography may be said to have proved itself capable of rendering, in the study of the crystalline rocks, a service equal to that which paleontology has already given in the deciphering and correlating of the fossiliferous strata.

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[1] This chapter was written as it now stands, excepting an occasional foot note, in 1887.

[2] Die Philosophie der Geologie, Pt. 3, Moderne Geologie oder mikroskopische Gesteinsstudien.

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Petrography, in its rapid development since the introduction of the microscope, has already passed through two distinct periods and is now entering upon a third and most important stage. At first methods had to be perfected for identifying the various constituents of crystalline rocks. During this stage the science was purely mineralogical, although its methods were necessarily somewhat different, both in their nature and in their application, from those of ordinary mineralogy. The attainment of this end required the study of a vast amount of material wholly without reference to its geological significance.[1]

The second period in the development of petrography was occupied with the investigation of practically unaltered rock-types, i. e., of rocks in which the minerals and structure produced by their original solidification are still readily discernible. It has been found from such studies that the relationship of the component minerals to one another, or rock-structure, expresses, to a large degree, the circumstances under which the original solidification took place, and hence the importance of the second stage in the development of modern petrography.

The most important problems presented by an unaltered massive or igneous rock relate to (1) its chemical composition and (2) to the conditions under which it was formed. The composition expresses itself, in a general way, in the nature of the component minerals, while physical conditions attendant upon the formation of the rock may be traced in its structure. Each of these has therefore been, in turn, the particular object aimed at during the first two periods of petrographical research.

But if petrography were able to solve satisfactorily all the problems presented by the unaltered massive rocks, it would even then be prepared only to commence its most difficult and most important mission. Rocks are in reality far from being the dead, inert, stationary masses which they appear to the ordinary observer. The fascinating study of chemical geology, especially when aided by the microscope, shows them to be in a state of almost constant change. It is true that some of the oldest rocks seem to have suffered hardly any alteration since they were first formed, but most of them are ever active laboratories where old products are being pulled to pieces and new ones built up. The tracing out of such changes is an important aim of petrography in its present stage.

The student at the microscope wonders at the minute bubbles which he so often finds inclosed in the little cavities in quartz. So delicately are they poised that they are sensitive to all the slight oscillations of temperature that constantly pass through the microscopic section, and the little prisoners keep up a never-ending movement, as though beat-

[1] The writer has given an account of the development of these methods in a small pamphlet, entitled "Modern Petrography," published as No. 1 of the Monographs of Education, by Heath & Co., of Boston.

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ing against every side of their narrow cell in the vain search for an exit. Scarcely less delicate seems to be the equipoise between the various chemical compounds in the earth's crust and the surrounding physical conditions under which they exist. Like the constant changes of temperature which pass through the slide are the changes in physical conditions to which a rock-mass is subjected. With these comes a state of more or less unstable equilibrium to the chemical compounds, and, like the vibrations of the bubble, molecular movements and rearrangements result.

There are two distinct kinds of alteration which take place in a solid rock-mass, dependent, of course, on the nature of the changed physical conditions. These are:

(1) *Metamorphism;* or the passage, under circumstances of high temperature or pressure, or both, of less crystalline into more crystalline compounds; or the change of minerals into others, not less crystalline or insoluble than themselves.

(2) *Decomposition or weathering;* the passage, under ordinary atmospheric conditions, of crystalline rock constituents into compounds less crystalline and more soluble than themselves. This is accomplished generally by hydration or carbonatization.

Both of these processes are frequently seen to have gone on in succession in the same rock-mass, the latter more or less completely effacing the effects of the former. While distinct, both processes agree in being atomic and molecular rearrangements in a solid mass, necessitated by some change in external conditions. The differences in these conditions, however, produce widely different results; and all of these again are essentially different from those produced by the solidification of a liquid magma.

The student of the crystalline rocks can distinguish in a general way four classes of constituent minerals, and this is true in spite of the fact that the same species may be represented in two or more of these classes.

(1) Original minerals of the acid rocks, formed by solidification of a magma in a state of aqueo-igneous fusion or by the aid of mineralizers; e. g., quartz, orthoclase, mica, zircon, etc.

(2) Original minerals of the basic rocks, formed from a state of dry fusion; e. g., plagioclase, augite, olivine, etc.

(3) Metamorphic minerals, formed, as above explained, from original minerals; e. g., hornblende, albite, biotite, zoisite, garnet, staurolite, andalusite, etc.

(4) Decomposition minerals; e. g., chlorite, quartz, carbonates, the hydroxides, etc.

Such a division, though necessarily not a sharp one, is still not unwarranted and shows how it is possible, with the aid of the microscope, not merely to study the composition of a rock in its component minerals, or the conditions under which it was first formed in its

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structure, but also to trace out life histories. We may discover not only the conditions under which a rock-mass solidified, but we may learn as well something of all the conditions to which it has subsequently been subjected.

Metamorphism, or the recrystallization of rocks, whether massive or stratified, igneous or sedimentary, is as varied in its results as the materials acted upon and the agencies which produce it. How true this is may be seen where the cause of the change is local and well understood, as in the numerous instances of contact-metamorphism which have been studied in detail during the last fifteen years. Here the alteration produced by the same eruptive mass is different in a shale from that in a sandstone, and in each the alteration is quite distinct from that produced in a limestone. If intrusive rocks fall within the range of influence, the effects produced in them are again different; while still wider variations are noticeable if the character of the active or metamorphosing rock be changed. This may be seen in the contrast between the effect produced by a mass of granite and a mass of diabase upon the same surrounding rock. Still other differences are traceable to the probable action of vapors, as in the case of a local development of tourmaline or topaz within the limits of a granite contact zone.

How much greater then might we expect the differences to be which all the complicated and imperfectly understood conditions of regional metamorphism produce. Many rocks occupying large areas exhibit a character very similar to that of rocks which have been produced by contact-metamorphism, without there being any cause to which the alteration can be so directly attributed. In some schists, like those of the Ardennes Mountains[1] and those of Bergen in Norway,[2] and in many limestones, metamorphic minerals have been extensively developed without the total obliteration of organic remains. In the case of other rocks, of essentially the same character though perhaps more crystalline, the internal evidence or the stratigraphical relations are enough to prove that they are metamorphosed sediments.

Many of the so-called crystalline schists present features of both composition and structure which are strikingly similar to those of rocks of undoubted metamorphic origin, but nevertheless we have at present but few data for constructing a satisfactory explanation of the origin of these enigmatical formations. Theorizing in regard to them has done its best, and has succeeded in introducing only confusion and disagreement. As before remarked, the variety here is far too great to be accounted for by a single hypothesis, however broad. Many agencies have been at work, whose exact nature and importance only the most laborious and patient investigation can show. In working in Archean

[1] A. Renard: Les roches grenatifères et amphiboliques de la région de Bastogne. Bull. Mus. Roy. Hist. Nat. Belgique, 1882, vol. i, pp. 1–54.

[2] H. H. Reusch: Silurfossiler og pressede Konglomerater i Bergensskifrene, 1882. Germ. transl. by by R. Baldauf.

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geology the only safe method is to free the mind completely from all traditions and theories—to start with the idea that almost nothing is known with certainty and that everything is to be discovered. The facts must be most critically observed and considered, without too great a tendency to use them at once for the deduction of general principles. Only such conclusions as can not be doubted by any one who will take the pains to examine the facts are of real value to the advance of archean geology; and every careful student in the field must realize how slow and difficult such an advance must be. Detailed analyses of the workings of some well recognized agency, made where the action has been as little as possible disguised and complicated by the action of other agencies, must yield valuable assistance in the penetration of the mysteries which now everywhere surround the prefossiliferous formations of the earth's crust. Such work has been done in Europe and has been begun in America. The little that has already been accomplished in this manner is full of promise for the future. The most striking example of work of this kind is perhaps that of Lossen in the Hartz Mountains, and it is with the sincerest appreciation of his method and results that the present studies have been prosecuted.

If it be granted, as it must be, by every impartial observer that such a thing as regional metamorphism does exist—that certain rocks, when they are subjected to enormous strains, and are upheaved, crushed, and crumpled do become more crystalline or have their crystallization altered—then we have a well recognized agency whose particular results are worthy of patient and detailed study. What part regional metamorphism has had in the production of the archean rocks as a whole, future years must show. This question lies wholly without my present purpose; and yet it is hoped that an extended investigation of a particular phase of it may aid in the final solution of the problem.

The investigation was undertaken with a firm conviction of the peculiar advantages offered by eruptive rocks for the accurate tracing of progressive metamorphism, an advantage which Prof. A. K. Lossen seems to have been the first to emphasize, if we may judge from the following extract from one of his papers. He says:[1]

I attribute the extreme value of such metamorphosed eruptive rocks for the general theory of metamorphism to the fact that they are certainly known to have been derived from a solid rock of definite mineral aggregation, average chemical composition and structure. In the primary minerals and structures of the igneous rocks we possess a well known quantity, upon which we can base our conclusions—a definite scale according to which the nature and amount of those secondary minerals and structures characterizing the metamorphic rocks can be measured. Frequently the certain, incontestable fact of pseudomorphism proves the secondary alteration of these rocks in a much more general way than even the very exceptionally preserved fossil remains are able to prove the origin of metamorphosed sediments.

[1] Den hohen Werth dieser metamorphischen Eruptivgesteine für die Lehre vom Metamorphismus fand ich darin, dass ein von Haus aus *festes Gestein von ganz bestimmter Mineralaggregation, chemischer Durchschnittszusammensetzung und Structur*, zuverlässig als ihr Muttergestein angegeben werden kann. In den primären Mineralien und primären Structuren der Erstarrungsgesteine besitzen wir eine

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There is no student of mineralogy who has not been struck with the great similarity which exists in the composition of so many of the rock-forming silicates.

We have after all a very small number of bases in these silicates and they are often combined in almost the same proportion in minerals which show the greatest disparity of crystal form, physical properties, and mode of occurrence. It seems to be oftentimes more a matter of external condition rather than of chemical composition, which determines what particular mineral is formed; and the equipoise between the existence of a certain silicate and the external conditions is often so delicate that a mere change in the latter is alone sufficient to destroy the mineral as such and to cause it to change to some other modification or compound. The recent discoveries of the alterations which dimorphous bodies, like leucite or tridymite undergo, show how this may be accomplished without chemical change. The breaking up of a mineral into an aggregate of two or more is not less common; as for example, the passage of plagioclase into zoisite and albite (saussurite), or of spodumene into albite and eucryptite (the β-spodumene of Brush and Dana.)[1] This subject has lately been elaborated by Prof. J. W. Judd in his presidential address before the Geological Society of London, and in many others of his recent papers.[2]

Rocks whose component minerals are so delicately balanced to accord with the particular set of conditions under which they were formed, must be peculiarly subject to alteration when these conditions are changed; and for this reason the writer has before insisted that eruptive rocks must be even more liable to metamorphism than the sediments which contain them.[3]

The advantage, then, of eruptive rocks, especially of basic eruptive rocks, for the study of metamorphic processes is, as Lossen has remarked with so much force, because we have in them a set of minerals and structures which can with certainty be referred to eruptive conditions, i. e., conditions of fusion. These, at least for the basic rocks, may be easily reproduced in the laboratory, as has been so successfully done by

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wohlbekannte Grösse, die wir unserem Urtheil zu Grunde legen können, einen festen Maassstab, an welchem Art und Grad jener secundären Mineralien und secundären Structuren gemessen werden können welche die Natur des metamorphischen Gesteins mehr oder weniger ausmachen. Vielfach ist es geradezu die sichere, unanfechtbare Thatsache der Pseudomorphosenbildung, die in solchen Gesteinen in viel allgemeinerer Weise beweisend für die Umbildung eintritt, als die nur unter besonders günstigen Umständen erhaltenen Petrafacten in den metamorphisirten Sedimenten. Jahrbuch der königlichen preussischen geologischen Landesanstalt u. Bergakademie für 1883, Berlin, 1884, p. 620.

On page 619 ibid., Lossen in a note gives the following list of references to his former remarks on this same important topic: Zeitschrift der deutschen geologischen Gesellschaft, vol. 21, p. 298, 1869; vol. 24, pp. 706, 707, 763, 1872; vol. 27, pp. 451 and 969, 1875; vol. 29, p. 360, 1877; Sitzungsberichte der Gesellschaft naturforschender Freunde in Berlin, Mch., 1878; Jan., 1880, and Nov., 1883; Jahrbuch der köngl. preuss. geologischen Landesanstalt für 1880, p. 12; für 1881, p. 43, and finally in the Erläuterungen zur geologischen Specialkarte von Preussen und den thüringischen Staaten. Blätter: Harzgerode (p. 79); Wippra (pp. 27, 43); Schwenda (p. 34).

[1] Am. Jour. Sci., 3d ser., vol. 20, 1880, p. 257, and Zeitschr. Kryst. u. Mineral., vol. 5, p. 192.

[2] Quar. Jour. Geol. Soc. London, vol. 43, 1887, Proc. pp. 54–82.

[3] Bull. U. S. Geol. Survey, No. 28, p. 9, 10.

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Messrs. Fouqué and Michel-Lévy, of Paris.[1] The exact mineral association and structure of diabase and other basic igneous rocks may be synthetically reproduced by simple dry fusion, and there is no indication whatever that they are ever produced in nature by any other means. The finding therefore of such characteristic structure, even where they have been more or less disguised by subsequent changes, at once furnishes a definite and certain starting point. We know what the original character of the rocks in question was and the conditions under which it was formed; and the careful minute study of the changes which the original component minerals have undergone, when taken in connection with the external physical conditions to which the rock mass has been subjected, can but yield useful results to geological science.

HISTORICAL OUTLINE OF STUDIES ON THE METAMORPHISM OF ERUPTIVE ROCKS.

Notwithstanding the great importance which has always attached to the idea of metamorphism, it is only within recent years that it seems to have been regarded as applicable to any but sedimentary rocks. With Hutton, who may practically be considered the originator of the idea, and with Lyell, to whom we owe the term which describes it, *metamorphism was the gradual consolidation, by means of the earth's internal heat, of sunken and buried strata*, whose original parallel structure was not wholly obliterated by the change. So strong has the power of this tradition become, that it is not easy to overcome it even at the present time. Nor after the discovery and satisfactory explanation of secondary (slaty) cleavage in rock-masses, was the case much better. The distinction between foliation and stratification was accepted as radical, and it was generally conceded that the former was secondarily developed in solid masses as the effect of pressure, and yet we hear of it chiefly in sedimentary rocks—in slates and shales. The eruptive rocks seem to have been regarded as too hard and unchangeable to be affected even by the enormous forces which upheaved a mountain chain. How untrue this is we are daily learning from the study of rocks undoubtedly eruptive, which possess a pronounced schistose structure.

As we now look back over a century of discussion and investigation of metamorphism, the total neglect of eruptive masses, save as an active agent in the change, seems surprising. Daubrée, in his admirable essay on the subject,[2] has much to say of change of structure, and yet he makes no allusion to eruptive rocks as being subjected to it. Delesse, in the second portion of his "Studies of Metamorphism"[3] which treats of regional or normal metamorphism, devotes considerable space to the metamorphism of eruptive rocks, but his conclusions are not such as at the present time deserve attention. He maintains that by some

[1] Synthèse des minéraux et de roches, Paris, 1879.

[2] Études et expériences synthétiques sur le métamorphisme, etc., Mém. présentés par savants à l'Académie des sciences, vol. 17, 1862. Translated in the Smithsonian Annual Report for 1861, pp. 228–304.

[3] Études sur le métamorphisme des roches. Ouvrage couronné par l'Académie des sciences. Paris, 1869.

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vague process of "general metamorphism" volcanic rocks are changed to plutonic. Thus a trachyte becomes a granite; and a trap, a diorite. The absence of volcanic rocks in the oldest formations is accounted for by the great length of time during which these have been subjected to metamorphosing agencies. The original plutonic rocks are considered to be capable of little or no change.

One of the first truly scientific studies of the metamorphism of eruptive rocks, based purely on careful observation of the facts, was that of Lossen in the Hartz Mountains. Here it was possible to trace the numerous diabase dikes and larger areas of more coarsely crystalline gabbros, along with the schists in which they were inclosed, from their unaltered to their most highly altered form. As early as 1872 he wrote as follows:

I shall begin with igneous rocks which have been altered in situ and with their (final) change into crystalline schists. The fact that massive rocks, which frequently possess a parallel structure as an original feature, may, by metamorphic processes, be converted into foliated, *but not on that account stratified*, beds is incontestable. In this manner granular diabase is converted into lenticularly foliated (flaserig) by the more or less complete passage of the cleavable augite into a scaly aggregate of chloritic minerals. The rock thus assumes a kind of schistose structure, as is often the case in the southwestern Hartz.[1]

The cause of the metamorphism, too, can be seen in some cases to be the eruption of large granite masses; in others, the orographic forces, which had crumpled and upheaved the entire district. Upon this subject Lossen says:

I have often emphasized the significance of those metamorphic regions in which eruptive rocks—interbedded in the schists and like them passively subjected to dislocation and mountain-making forces—have undergone about the same substantial and structural alterations as the inclosing schists; nor is it material whether this result has been accomplished within the contact-zone of some intrusive granitic mass or by dynamic (dislocation) forces properly so called.[2]

Massive rocks may therefore be passively subjected to the influence of either contact or regional metamorphism.

Instances of the former seem never to have received their merited share of attention, and yet they have been mentioned in many different regions. Allport described dolerites which had been altered by adjacent eruptive granites in Cornwall.[3] In France Michel-Lévy has found

[1] Ich beginne mit den in situ umgewandelten Erstarrungsgesteinen und deren Umwandlung zu krystallinischen Schiefern. Die Thatsache, dass durch metamorphische Processe massige Gesteine, die häufig bereits eine ursprüngliche plane Parallelstructur besitzen, in schiefrige, *darum aber noch nicht in geschichtete*, umgewandelt werden, ist unbestreitbar. So gehen die körnigen Diabase dadurch häufig in flaserige über, dass das blätterig brechende augitische Mineral ganz oder theilweise in ein schuppiges Aggregat eines chloritischen Minerals umgewandelt wird, wobei das Gestein eine Art schiefrige Structur annehmen kann, wie dies im Südost Harz nicht selten der Fall ist. (Zeitschr. Deutsch. geol. Gesell., Berlin, vol. 24, p. 763, 1872.)

[2] Merfach bereits habe ich die Bedeutung solcher metamorphischer Gebiete hervorgehoben in welchen zwischen den Schichten eingeschaltete und nur passiv am Faltungs- und Gebirgsbildungsprocesse betheiligte Eruptivgesteine in annähernd demselben Grade wie die daneben anstehenden Schichtgesteine substantielle und structurelle Umwandlungen, sei es in der Contactsphäre der in die Faltung eingreifenden eugranitischen Eruptivmassen, sei es durch den Dislocationsprocess schlechthin, erlitten haben. (Jahrb. preuss. geol. Landesanstalt für 1883, p. 619.)

[3] On the metamorphic rocks surrounding the Land's End mass of granite. Quarterly Journal Geol. Soc., London, vol. 32, 1876, p. 422.

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similar effects produced in the Cambrian diabases,[1] and Barrois mentions diorites ("diorite modifié") which have been modified by the same cause.[2] Still more recently Brögger has discovered the same class of phenomena in dikes of augite porphyrite which penetrate the strata of the classic silurian region near Christiania.[3]

The most exact and satisfactory accounts of such rocks are, however, those given by Lossen of the diabases which fall within the limits of the Ramberg granite contact zone in the Hartz Mountains.[4] The effect of the granite has been to produce alterations in the eruptive diabases quite analogous to those usually brought about by orographic forces. The augite has been changed to uralite, which surrounds the core of the original mineral in a double zone, the inner one being colorless and dotted with magnetite, while the outer one is composed of a more compact, green, and pleochroic hornblende.[5] The labradorite of these diabases has been saussuritized; their ilmenite has been changed to sphene (leucoxene) and their pyrite to pyrrhotite. Biotite and garnet have also been occasionally developed. The characteristic diabase structure is recognizable so long as any of the augite or labradorite substance remains.

If the results described by Lossen are in reality wholly due to the influence of the intrusive granite mass, then we see that the similarity between the effects produced by contact metamorphism and regional metamorphism is just as close in the case of eruptive rocks as it is in that of sedimentary beds. The connection which exists between regionally metamorphosed areas and the disturbances to which such areas have been subjected appears to be a constant one. Indeed, aside from the local influences of intrusive masses, the amount of metamorphism may be said to be in all cases proportional to the pressure or strain to which the rock in question has been subjected. The recent recognition of this fact has brought into favor the term "*dynamic metamorphism*,"[6] which, in a way, expresses the agency or process to which the change may be attributed.

Rocks are not metamorphosed by pressure alone, and yet the importance of this agency would appear to be greater than that which has commonly been assigned to it. Other factors, especially heat and moisture, have also played an important part in the changes, but their efficacy is in large measure due to the direct results of pressure upon

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[1] Sur les roches éruptives basiques Cambriennes du Mâconnais et du Beaujolais. Bull. Soc. géol. France, 3 series, vol. 11, 1883, pp. 273–303.

[2] Le granite de Rostrenen, ses apophyses et ses contacts. Annales Soc. géologique du Nord, 1884, vol. 12.

[3] Spaltenverwerfungen in der Gegend Langesund-Skien. Nyt Mag. for Naturvidenskaberne, vol. 23, 1884, pp. 253–419.

[4] Ueber den Ramberg Granit und seinen Contact-Hof. Erläuterungen zu Blatt Harzgerode der geologischen Specialkarte von Preussen und der thüringischen Staaten. Vide also Jahrb. kön. preuss. geol. Landesanstalt für 1883, pp. 619–642; für 1884, pp. 56–112, and pp. 525–545.

[5] For an illustration of this structure, see Bull. U. S. Geol. Survey, No. 28, 1886, Pl. I. Fig. 2.

[6] "Mechanical metamorphism" of Heim and Baltzer, "Dislocation-M." of Lossen, "Dynamical-M." of Rosenbusch, "Stauungs-M." of Credner, "Pressure-M." of Bonney.

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the solid rock-mass. The crushing of rocks along fault or shearing planes allows here of the ready circulation of moisture and of a consequent increased distribution of heat. Rocks are hence most altered along such planes. The almost universal effect of such a crushing is made apparent by a microscopic examination of rocks which have been subjected to enormous pressure. We shall have occasion to cite numerous instances of this in the sequel. For the present we will state the three different modes in which an eruptive rock is altered when it undergoes regional or dynamic metamorphism, and mention the work of those who have been particularly successful in illustrating the action of all or any of them.

The three ways in which a massive crystalline rock may be modified by the action of orographic forces are:

I. Macro-structural; i. e., it may have its external structure (morphology) changed so as to become schistose or foliated.

II. Micro-structural; i. e., it may have its internal or microscopic structure (histology) wholly changed, either with or without an alteration of the last-mentioned sort.

III. Mineralogical; i. e., there may be a change in the nature of one or more of the component minerals, either with or without a change in the chemical composition of the rock as a whole.

Of course, any one of these kinds of change may be produced in a rock-mass alone, or any two, or even all three, may exist simultaneously in any relative degree of intensity.

Macrostructural Metamorphism.—It had already long been recognized that transversal or slaty cleavage could be produced in sedimentary beds by mechanical force,[1] when A. Heim, in his work on the "Mechanism of Mountainmaking," published in 1878,[2] directed attention to an almost new line of geological work, by showing in a very general way how the orographic forces effect the deformation of rock-masses. He insisted upon three main points:

(*a*) That the rocks were solid and rigid when they were acted upon.

(*b*) That by a moderate pressure, they are torn asunder and the thus formed open fissures ("klaffende Risse") are subsequently filled by material segregated from the rock ("adern"). If the mass is plastic rather than brittle, the strain is relieved by numerous slicken-sides ("Rutschflächen") ("*Umformung mit Bruch*").

(*c*) That by the most intense pressure this action becomes infinitely small or molecular, i. e., the form is altered without rupture ("*Umformung ohne Bruch*").

Heim lays great stress upon the fact, already emphasized by Suess,[3] that the massive or crystalline rocks which form the center of the Al-

[1] On slaty cleavage and allied rock-structures with special reference to the mechanical theories of their origin. By Alfred Harker. Rept. fifty-fifth meeting Brit. Assoc. Adv. Sci., in 1885, pp. 813–855, 1886.

[2] Untersuchungen über den Mechanismus der Gebirgsbildung im Anschluss an die geologische Monographie der Tödi-Windgällen-Gruppe. Basle, 1878. Vol. 2.

[3] Die Entstehung der Alpen. Wien, 1875.

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pine "massivs" were not themselves in any way instrumental in the elevation of the mountains. He gives an elaborate proof that these were solid long before the elevation; and were only *passively* subjected to the upheaving force, in the same way as the overlying sediments. Heim does not, however, seem to apply his laws of mechanical deformation to these crystalline rocks, as he might well have done, but regards their schistose or banded structure as probably an original character.

Other geologists were not long in recognizing the mechanical deformation of massive as well as sedimentary rocks. Daubrée is struck by the frequent gradual passage of massive rocks into schistose varieties of the same composition. He says that, in spite of his own strong leanings toward the "metamorphic theory," he can not possibly regard such a schistose structure as any sign of original stratification but must consider it as secondarily produced in the eruptive mass by pressure. He is, however, inclined to believe that this result was attained before the eruptive rock had wholly solidified.[1] H. H. Reusch, from his studies of the rocks near Bergen, in Norway, is also convinced that the frequent banding and gneissic structure in granite is secondary and a product of pressure, like slaty cleavage. Like Daubrée, he too thinks that it was accomplished while the rock was still somewhat soft, at the time of the faulting and dislocation to which the granite owed its own elevation, in a plastic state.[2] This idea that such pressure deformation could only take place in softened or in unsolidified rocks was particularly dwelt upon by Carl Friedrich Naumann. How thoroughly the objections to the deformation of rigid rock masses, as far as sedimentary deposits are concerned, are answered by the facts observed by Heim, we have already seen. The assumption of an identical process for the highly crystalline massive rocks seems, at first, to present great difficulties, but observations in all parts of the world are daily proving its necessity.

In 1879, Rothpletz[3] showed how the actinolite, or so-called greenschists near Hainichen, in Saxony, had been brecciated by pressure and the fragments shoved along more or less upon each other, so as often to produce an imperfect schistose structure. This, which has a close analogy to certain macrostructural modifications of the Lake Superior greenstones to be described in subsequent pages, allowed, as Rothpletz remarked, a much increased chemical action, which tended to alter the character of the rock. A. Baltzer, in his monograph on the Finsteraarhorn,[4] published in 1880, expresses himself as decidedly in favor of a mechanical metamorphism of the interior crystalline rocks. He says on page 244 of his work:

[1] Études synthétiques de géologie expérimentelle. Paris, 1879, p. 432.

[2] Die fossilien führenden krystallinischen Schiefer von Bergen in Norwegen. Deutsche Aufgabe von R. Baldauf, 1883, pp. 129, 130.

[3] Ueber mechanischen Gesteinsumwandlungen bei Hainichen in Sachsen. II. Die Breccienbildung des Aktinolithschiefers von Hainichen. Zeitschr. Deutsch. geol. Gesell, 1879, Vol. 31, p. 374.

[4] Die mechanische Contact von Gneiss und Kalk im Berner Oberland. Beiträge zur geologischen Karte der Schweiz. XX. Lieferung. Bern, 1880.

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I base my assumption that the parallelism of the mica-scales in abnormally stratified gneiss is conditioned by pressure, upon this transverse foliation. Just as slaty-cleavage is generated in the younger sedimentary rocks by pressure and mechanical deformation, so is it also in the crystalline schists. This may be proved in the case of the last named rocks, if other evidence is lacking, by its parallelism with the undoubted cleavage in contiguous sediments.[1]

Similar ideas have been more or less clearly expressed by Kjerulf, Brögger, Stapff, and other geologists, but one of the most important contributions to our knowledge of this, as well as of other phases of mechanical metamorphism, was made in 1884 by Prof. Johannes Lehmann in his work on the origin of the crystalline schists.[2] That author has collected an immense number of observations from Saxony, Bavaria, and Bohemia—especially in the "Granulite" district of the first named country, upon the detailed study of which he has spent many years. From these observations Lehmann reaches certain general conclusions of importance with reference to the mechanical metamorphism of solid massive rocks. These are stated in chapters 16 and 17 of his work. He regards gneiss as simply a structure form of granular feldspathic rocks, and according to the composition of these there may occur granitic gneiss, syenitic gneiss, dioritic gneiss, gabbro gneiss, etc. He thinks that the essential parallel structure of gneiss may be, but very rarely is, original. He finds no indication that any true gneisses were once sedimentary deposits, but he considers them all as igneous rocks ("Erstarrungsgesteine"), which, as a general thing, have acquired their present structure by stretching ("Streckung") in a solid state. Moreover, gneiss exhibits only the first stage of such a mechanical metamorphism. If the action of this process is more intense, finer grained and more evenly banded rocks result, which the author designates as granulite and felsite schist. According to Lehmann, therefore, all the massive crystalline rocks are subject to alterations in their structure through great pressure or tension. They become banded or schistose in proportion to the intensity of this action.

The observations of many workers in various regions since the publication of Lehmann's conclusions have tended to substantiate them. Mr. Hatch[3] has shown the secondary development of a schistose structure in the gabbros of the Tyrol, and the same thing has been done for the gabbros near Baltimore, Maryland.[4] Results very closely resembling those of Lehmann have recently been secured by Mr. J. J. H. Teall in the gabbro region of the Lizard, Cornwall, England.[5] This

[1] Auf diese transversale Schieferung gründe ich die Annahme dass der Parallelimus der Glimmerblättchen im anormal gelagerten Gneiss ebenfalls von Druckschieferung herrührt. Wie in den jüngern Sedimentgesteinen durch Druck und mechanische Umformungsprozesse transversale Schieferung entstand, so auch in den krystallinischen Schiefern. Bei letzteren kann sie, in Ermangelung anderer Anhaltspunkte, durch den Parallelismus mit einer unzweifelhaften Schieferungsrichtung in den angrenzenden Sedimenten nachgewiesen werden.

[2] Untersuchungen über die Entstehung der altkrystallinischen Schiefergesteine, etc., with Atlas of photographs. 4°. Bonn, 1884.

[3] Tschermak's mineral. u. petrog. Mittheil., vol. 7 (1885), p. 75.

[4] Bull. U. S. Geol. Survey, No. 28.

[5] Geol. Mag., London, November, 1886.

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investigator derives proof that the alteration in structure was accomplished after complete solidification from the relation of the rock to fault-planes. He says:

A rock must necessarily be solid before it can be faulted. Now, we find at Pen Voose near Landewednack, that massive gabbro passes over into gabbro schist at a fault-plane, and that the foliation in the gabbro is such as would be produced by a shearing motion parallel with the fault-plane. Taking all the facts into consideration, we appear to be justified in concluding that the foliation in the Lizard gabbros is the result of pressure or regional metamorphism.

C. Schmidt has also recently given us the results of his studies of certain eruptive porphyries in the central Alps, especially in the Windgällen group, the district particularly studied by Heim.[1] These, like the surrounding sediments, have been subjected to enormous pressure and strains and thereby have had developed in them a pronounced schistose structure, becoming in some instances veritable felsite schists. Still more recently H. H. Reusch has communicated his observations in the regionally metamorphosed district of Hardangerfjord, on the west coast or Norway.[2] Here he finds dikes of all sorts of eruptive rocks, both acid and basic, all rendered secondarily schistose parallel to the planes of the inclosing schists, without reference to the direction of the dikes themselves. This, therefore, can not possibly be due to either flow or cooling, but must be the result of pressure. Ch. E. Weiss observed the same thing in the quartz porphyry dikes of Thal, in Thuringia.[3]

Prof. T. G. Bonney, in his annual presidential address to the Geological Society of London (February, 1886), deals with the subject of metamorphism in general, and has much to say about the structural changes induced in holocrystalline massive rocks by pressure[4]. He distinguises between "*stratification-foliation*" and "*cleavage-foliation*," the latter being always secondarily produced by pressure.[5] This same cause also in some cases may produce a false bedding parallel to the cleavage-foliation, almost exactly similar to the bedding of sedimentary rocks, although of a totally different origin, and to this he applies the name "pseudostromatism."[6]

Microstructural metamorphism.—The statement of Heim that under sufficient pressure rock-masses became plastic, i. e., that they could be bent and crumpled by a true molecular movement within the mass, without rupture, seems to have been based entirely on a macroscopical study of exposures and specimens. Rocks, and even their constituent minerals, certainly do appear to the unaided eye to be stretched and contorted without any break in their continuity. Whether, however, this effect is accomplished by a truly molecular movement, as in a viscous body,

[1] Neues Jahrbuch für Mineralogie, etc., Beilageband 4, p. 388, 1886.
[2] Ibid., Beilageband 5, p. 56, 1887.
[3] Zeitschr. Deutsch. geol. Gesell., vol. 36, 1884, p. 858.
[4] Quar. Jour. Geol. Soc. London, vol. 42, 1886, Proc., p. 95.
[5] Ibid., p. 64.
[6] Ibid., p. 65.

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or by a breaking or crushing of the component crystals with a movement in the mass before it is recemented, is something that can not be well decided by the unaided eye. Such authorities as Gümbel[1] and Pfaff[2] at once took exception to the conclusions of Heim, and stated it as their conviction that, strictly speaking, there was no such thing as the deformation of rocks without rupture. Baltzer[3] could not decide between the conflicting views, but thought there was probably truth in each. The microscopical study of such bent and contorted rocks seems to show that the explanation of Gümbel is generally the true one. This was emphasized by J. Lehmann.[4] He calls attention to the fact that the conception of plasticity is not a simple one. We speak both of wax and of wet clay as "plastic," and yet the movement of the homogeneous body is different from that in the heterogeneous substance. In each the process of the deformation escapes the eye and the results appear the same; but in reality the first is molecular, the second caused by the slipping of the component particles (kaolin scales) over each other. In rocks the "plasticity" is of the second kind. Lehmann[5] says:

When rock-deformation has been accomplished by a breaking and sliding of the individual constituents upon each other, I think that I am still justified in calling it a deformation without rupture, provided the continuity of the rock-mass itself has been preserved and no fissures have been formed. * * * I recognize only that as rock-deformation with rupture when fissures, even though microscopic, traverse the rock independent of the individual constituents.[6]

Again he says:[7]

A plastic molding of the separate constituents, as is assumed by Heim, I have nowhere been able to discover. On the other hand, the maximum of resistance which a crystalline grain can offer to bending or crushing is very soon reached, and then ensues a pulverizing or chemical solution.[8]

Lehmann also particularly emphasizes the importance of the very much increased chemical action which such a crushing of the rock components permits. This had heretofore been almost overlooked by all the students of dynamic or mechanical metamorphism except Lossen. The ease with which a ready circulation and changed physical condition allow the destruction of certain chemical compounds, and the im-

[1] Das Verhalten der Schichtgesteine in gebogenen Lagen. Sitzungsberichte der kön. bayrischen Akademie. Math.-phys. Classe, vol. 4, p. 596, 1880 (reviewed by Rosenbusch in the Neues Jahrbuch für Mineral., 1882, Vol. 1, Referate, p. 221).

[2] Der Mechanismus der Gebirgsbildung. Heidelberg, 1880, p. 140.

[3] Die mechanische Contact von Gneiss und Kalk im Berner Oberland, Bern, 1880, p. 210.

[4] "Untersuchungen über die Entstehung der altkrystallinischen Schiefergesteine, etc.." Chap. XVI.

[5] Ibid., p. 245.

[6] Ich glaube sogar mit Recht eine Gesteinsformung, bei welcher nur die einzelnen Gemengtheile zerspalten und sich an einander verschieben, als eine bruchlose bezeichnen zu könen, wenn das Gestein seinen Zusammenhalt bewahrt hat und keine das Gestein durchsetzenden Risse vorhanden sind. * * * Eine Gesteinsformung mit Bruch erkenne ich erst dann an, wenn Risse, und mögen es auch mikroskopische sein, unbekümmert um die Einzelgemengtheile das Gesteinsgewebe durchsetzen.

[7] Ibid., p. 249.

[8] Eine plastische Formung der Einzelgemengtheile, wie sie Heim annehmen zu müssen glaubt, habe ich niemals gefunden; vielmehr erreicht die Biegung oder Zusammendrückung eines Krystallkorns sehr bald das Maximum und erfolgt dann eine Zertrümmerung beziehungsweise auch eine chemische Auflösung.

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mediate formation of others out of their elements, is calculated to preserve the continuity of the rock-mass in spite of extensive stretching or compression.

Such chemical changes will form the subject of the following section. Here we are concerned only with the mechanical deformation of the elementary minerals.

The effects of pressure will naturally be first noticeable upon an elastic mineral like mica. A bending of the lamellæ is well known to result frequently from even the slight movement of an eruptive magma before its complete solidification. Wherever, therefore, so sensitive a mineral presents no pressure effects when more brittle substances show them, it is fair to assume that the mica has been secondarily developed during the action of the pressure.

Harder minerals, like augite or feldspar, under the first action of strain, before their cohesion is overcome, appear to have twinning lamellæ developed in them parallel to certain planes—and most abundantly where the strain is the most intense. To this succeeds a cracking of the crystal, with often a considerable separation of the parts and a filling of the interstices by newly deposited substance.[1] A still more intense pressure accompanied by a shearing stress seems to produce a regular granulation of the larger crystals, so that around their edge they pass into a mosaic-like aggregate of fine interlocking grains. This process in the case of augite, as in the Saxon "Flaser-Gabbros," is attended by uralitization, or the production of secondary amphibole. The resulting structure, in which larger grains are separated by a finer mosaic, has been called by Törnebohm, who observed it in certain Swedish granites, "mortar-structure" ("Mörtel-Structur").[2] This granulation, with increasing strain, may extend farther and farther inward until finally the entire crystal is replaced by a fine mosaic of interlocking grains. When produced under the influence of sufficient pressure, it may, of course, give rise to a pronounced banded or schistose structure.

The action of strain upon the hardest and most brittle of the rock-forming minerals—quartz—seems to result in cracking and breaking, rather than in bending it. Crystals which appear in hand-specimens to be stretched out into lenses, are shown by the microscope to be composed of smaller grains, more or less different in their optical orientation. Of this mineral Lehmann says:[3]

The phenomena which the quartz of stretched rocks exhibit manifest themselves under the polarizations microscope in the unequal extinction of different fields, and

[1] See Lehmann's Atlas, Pl. 6, Figs. 3, 6, and Pl. 21, Figs. 3, 6.

[2] Några ord om granit och gneis. Geol. Föreningens Stockholm Förhandl., vol. 5, pp. 233–248, 1880–81 (review in the Neues Jahrbuch für Mineral., 1881, vol. 2, Referate, p. 50). Törnebohm, in this paper, considers this as an original structure. Kjerulf designates all such dynamic changes as are manifested in a movement among the fragments of broken crystals as "*Kataklas-structur*." He distinguishes three grades of intensity. See Grundfjeldsprofilet ved Mjøsens sydende. Nyt Mag. for Naturvidenskaberne, vol. 29, p. 215, 1885 (review Neues Jahrbuch für Mineral., 1886, vol. 2, Referate, p. 244). See also Rosenbusch: Mikros. Physiog., vol. 2, 2d ed., p. 42, 1887.

[3] Untersuchungen über die Entstehung der altkrystallinischen Schiefergesteine, etc., p. 250.

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then in a somewhat more exact separation of these fields. We imagine that we can detect sharp boundary lines without being able to certainly prove their existence (and in reality they are due merely to tension). Finally, however, the individual grain does really break up into separate interlocking parts, which at first are but slightly changed in their orientation. Nevertheless, toward the edge and in the more compressed portions these parts are quite irregularly orientated and participate in the composition of the ground-mass. True bending of quartz is unknown to me. It is shattered very easily, and, as it seems, is as readily subject to chemical solution.[1]

Prof. Ch. E. Weiss, of Berlin, describes remarkably deformed quartzes in the schistose porphyries occurring in the almost horizontal mica schist near Thal in Thuringia.[2] This rock forms dikes which cut across the bedding of the schist and send apophyses in a horizontal direction between its layers. The schistose structure of the porphyry was formerly considered to be a flow structure, but Weiss has shown that this can not possibly be, as it runs in every case *parallel to the bedding of the mica-schist without reference to whether this is parallel or perpendicular to the walls of the dike.* The porphyritic quartz crystals in these rocks are drawn out into long, pear-shaped or tadpole-like ("kaulquappenähnlich") forms, which follow the direction of the schistose structure. This is accomplished sometimes with, sometimes without, a rupture of the quartz substance, and produces what Lossen calls tailed-quartzes. ("Schwänzchen-quarz.")[3]

It is remarkable that the porphyritic feldspar crystals of these rocks have suffered far less deformation than the much harder quartzes, an observation which, as we shall see, is abundantly substantiated in the schistose porphyries of the Lake Superior region. The phenomena exhibited by the Thuringian rocks, although left without explanation by Weiss, are referred without hesitation by Rosenbusch to the effects of dynamic metamorphism.[4]

Rosenbusch also remarks that, as a rule, the peripheral granulation ("randliche Kataklase"), characteristic of the coarse-grained, granitic rocks, is wanting in the porphyries. This he attributes to the structure, for in the granular rocks under great pressure the grains rub against each other, while in porphyritic rocks the larger crystals are imbedded in a homogeneous matrix, so that they are either only optically disturbed or completely pulverized.[5]

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[1] Die Erscheinungen, welche der Quarz gestreckter Gesteine zeigt, bekunden sich unter dem Polarisationsmikroskop in einem ungleichen Dunkelwerden verschiedener Felder, dann in einer schärferen Abgrenzung derselben; man glaubt Begrenzungslinien zu sehen, ohne dass solche thatsächlich nachzuweisen wären—sie beruhen wohl nur auf Spannungen—endlich zerfällt das einheitliche Korn aber wirklich in einzelne, zackig begrenzte Theile, die zunächst nur wenig aus ihrer Lage gedreht erscheinen; gegen den Rand des Korns und in stärker gepressten Theilen jedoch wirr durcheinanderliegen und an der Zusammensetzung der feinkörnigen Grundmasse sich betheiligen. Eigentliche Biegungen von Quarzen sind mir nicht bekannt; er zerstückt und zerfällt sehr leicht und erliegt wie es scheint ebenso leicht einer chemischen Auflösung.

[2] Jahrbuch preuss. geol. Landesanstalt für 1883, pp. 213–237, Berlin, 1884; and Zeitsch. Deutsch. geol. Gesell., vol. 36, 1884, p. 858. Cf. J. G. Bornemann: Jahrbuch preuss. geol. Landesanstalt für 1883, pp. 383–409, Berlin, 1884.

[3] Zeitsch. Deutsch. geol. Gesell., vol. 34, 1882, p. 678.

[4] Die massigen Gesteine, 2d ed., 1886, p. 214.

[5] Ibid., p. 413.

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Dr. C. Chelius describes compressed and schistose granite porphyries from the northern portion of the Odenwald (Hesse-Darmstadt). In these the ground-mass is quite fine-grained, but where small areas of it have been protected, as it were, by large porphyritic crystals *it has nearly twice as coarse a grain.*[1]

It would appear to be quite generally the case that porphyritic massive rocks, when subjected to great pressure, develop the so-called "Augen structure." The larger crystals are only partially pulverized, and have on either side of them, in the direction of the schistose structure, a mosaic of their own débris, arranged like the "crag-and-tail" of a glaciated ledge. This has been observed and admirably described by Lehmann[2] in the Saxon granulites, by Teall[3] in the gabbros of the Lizard district, Cornwall, and by Bonney.[4]

Mineralogical metamorphism.—This is undoubtedly the most important phase of metamorphism in eruptive as well as in sedimentary rock masses. It always accompanies such mechanical deformation—whether macroscopical or microscopical—as has been already described; but, while such dynamic processes may greatly facilitate chemical action or molecular rearrangement, they are by no means always necessary to bring them about. The adjustment between the chemical combinations and external conditions is so delicate in the inorganic world as to make the difference, in this respect, between minerals and living organisms seem rather one of degree than of kind. This point has been elaborated by Professor Judd in his recent annual address before the Geological Society of London (February 18, 1887).[5] Wadsworth[6] has also insisted that the changes in the mineral world are due to the passages from states of less stable to those of more stable equilibrium; but, as Judd justly remarks, the cycle of changes may be infinite because the stability of a compound depends upon its surrounding conditions. With a change of these, a state which was once stable becomes unstable. No student of mineralogy can fail to appreciate the extreme delicacy of the equipoise. Any one who has produced artificial twinning-lamellæ in feldspar or calcite, or watched sulphur or boracite or tridymite or leucite pass from one modification into another, must acknowledge the importance of paramorphism in the formation of rocks. But changes of minerals accompanied by changes in the chemical nature of the compound are still more common. These may consist (1) in the breaking up of one molecule into two or more, with but little replacement of substance, as in the formation of saussurite from labradorite, or of β spodumene (albite + eucryptite) from spodumene; or (2) in a reaction which takes place between two contiguous minerals, each supplying a part of

[1] Notizblatt des Vereins für Erdkunde zu Darmstadt, 4. Folge, Heft 5, 1885, p. 29.

[2] Untersuchungen über die Entstehung der altkrystallinischen Schiefergesteine, etc. Bonn, 1884.

[3] Geol. Mag., London, Nov., 1886.

[4] Presidential address to the Geological Society, Feb., 1886., Quart. Jour. Geol. Soc. London, vol. 42, Proc., p. 96.

[5] See also the writer, Pop. Sci. Monthly, Sept., 1889.

[6] Nature, March 3, 1887, p. 417.

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the substance necessary to form a new compound of intermediate composition, more stable for the then existing conditions than either. Such a case is the formation of a hornblende zone between crystals of olivine or hypersthene and plagioclase, or of the so-called "kelyphite" zone between pyrope and serpentine; (3) in more complicated and less easily understood chemical reactions, like the formation of garnet or mica from materials which have been brought together from a distance and under circumstances of which it is at present impossible to state anything with certainty.

All such changes involving an actual change in the chemical composition are best designated in contrast to those produced by paramorphism, as metasomatic.[1]

Of course all of these metamorphic changes of a mineralogical character—whether paramorphic or metasomatic—may go on in all conceivable proportions in a rock mass at the same time. They are often accompanied by changes in the original structure of the rock, but not of necessity, although such changes of structure can not be accomplished without chemical alteration.

Chemical changes in minerals and rocks have occupied the attention of mineralogists and chemists from the beginning of the century, and yet it is almost exclusively in sedimentary rocks that such studies have been carried on. Only within recent years have the mineralogical metamorphoses which take place in eruptive rocks commenced to receive their proper share of consideration. Lossen, Törnebohm, and J. Lehmann were the first in Europe to recognize the importance of such investigations; while it will ever remain one of the most signal services which Dr. Wadsworth has rendered to petrography that he was the first in America to fully grasp their significance and to emphasize it.

It would be quite beyond the purpose of the present paper, even if it were possible, to give a complete summary of all that has been done on the subject of chemical changes in eruptive rocks. In this place the attempt will be made only to trace out historically some of the more important alterations which have a direct bearing upon the rocks forming the subject of this investigation. Important and wide-spread phases of the metamorphism of eruptive rocks—such, for instance, as serpentinization—which are not exemplified within the area studied will not be here considered. On the other hand, minor details or local modifications of well known and universally recognized processes will be elaborated in the course of the special petrographical descriptions (Chapters II–V) and summarized in Chapter VI.

The points which will be historically considered in this chapter are the following:

(1.) *Uralitization*, or the secondary origin of hornblende, both fibrous and compact, from pyroxene.

[1] This term is preferred to *methylosis* of King and Rowney ("An old chapter of the geological record with a new interpretation;" London, 1881), and Bonney (Quart Jour. Geol. Soc., London, vol. 42, 1886, Proc., p. 59), and to *metachemic* of Dana (Am. Jour. Sci., 1886, 3d series, vol. 32, p. 70), because it is at present so much more widely used and hence so much more intelligible.

(2.) *Chloritization.*
(3.) *Epidotization.*
(4.) *Formation of the viridite (chlorite) epidote aggregate.*
(5.) *Saussuritization.*
(6.) *Formation of the albite mosaic.*
(7.) *Sericitization.*
(8.) *Alterations of titanic-iron.*

Uralitization.—Ever since the classic record of observations made by Gustav Rose in the Ural Mountains in 1830,[1] the fact has remained undisputed that pyroxene sometimes changes to an aggregate of amphibole needles which often preserve by their arrangement the original augitic form. It was not long before other similar occurrences were discovered, notably in Scandinavia and the Tyrol. Still, these localities were regarded as exceptional, and it was impossible that the full geological importance of Rose's uralite should be appreciated without the aid of the microscope. With the help of this instrument it was soon discovered that the smaragdite of the saussurite gabbros or euphotides was a secondary hornblende which had originated from the diallage. As the number of observers and observations increased, instances of the undoubted passage of every sort of pyroxene into a fibrous amphibole grew constantly more and more abundant. It would be useless to attempt to trace out these discoveries in detail. It is enough merely to mention the names of Rose, Vom Rath, Fischer, Hagge, Zirkel, Von Lasaulx, Rosenbusch, Törnebohm, Svedmark, Sjögren, Becke, Kloos, Michel-Lévy, Allport, Phillips, Teall and Hatch, in Europe, and of Hawes in this country, to recall the accuracy and value of the facts recorded, while among the first to see further than mere facts and to grasp the full geological significance of this wide-spread change may be placed Lossen, Lehmann, Reusch, Wadsworth and Irving.

The alteration of pyroxene to hornblende is almost universally alluded to as paramorphism, and such, indeed, it may be in some instances. Still, many investigations go to prove that it is very often, perhaps always, accomplished by chemical change. The original uralite of Rose was too soft and hydrous to be compared with hornblende. The studies of Forschhammer, Rose,[2] and Svedmark[3] showed that when augite changed to fibrous hornblende, magnetite and often calcite was separated out between the needles. A recent opinion by Rosenbusch on this point is as follows:

> This uralitization can hardly be regarded as a simple act of molecular rearrangement; we should rather expect that a part of the lime contained in the augite would pass into other combinations, and, in fact, epidote is an almost constant companion of uralite.[4]

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[1] Poggendorff Annalen, vol. 22, 1831; vol. 31, 1834, p. 617; also Reise nach dem Ural, vol. 2, p. 342.
[2] Zeitschr. Deutsch. geol. Gesell. Berlin, vol. 16, 1864, p. 6.
[3] Neues Jahrbuch für Mineral., 1877, p. 99; Mikros. Physiog., vol. 2, 2d ed., p. 185; vol. 1, p. 472.
[4] Diese Uralitisirung kann nicht wohl ein einfacher Act molecularer Umlagerung sein, es ist viel mehr zu erwarten, dass ein Theil des Kalkgehalts des Augits in andere Verbindungen übergehe und thatsächlich ist Epidot ein nahezu constanter Begleiter des Uralits.

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Dr. B. Harrington, of Montreal, has carefully analyzed three stages of alteration between pyroxene and a secondary fibrous hornblende resulting from it, and has found that during the change there has been a great loss of lime and a gain of magnesia, silica, and the alkalies.[1] The specimen investigated was one of the excellent examples of uralite from the apatite mines near Ottawa, Canada, similar to those named by Thomson "Raphilite."[2]

Mr. J. J. H. Teall has also recently discussed this point in connection with his studies of the alteration of the Scourie dike,[3] and is of the opinion that the oxidation of iron from the ferrous to the ferric state is incident to the change of augite to hornblende.

While the alteration of almost any pyroxene into fibrous hornblende has now become a universally recognized fact, the possibility of the change of this mineral directly into compact hornblende is by no means so generally admitted. So admirable an observer as J. H. Kloos has recently based his distinction between primary and secondary amphibole in the Black Forest gabbros entirely upon their compact or thin fibrous character.[4] Still, the work of many investigators shows that this is by no means a reliable criterion in all cases.

Svedmark found in 1876 that the pyroxene of the Vaksala porphyry passed into an aggregate of stout, compact amphibole needles.[5] In 1877 Streng described compact brown hornblende in the Minnesota gabbros, which he considered to have originated from the diallage;[6] and in 1878 Dr. George W. Hawes described and figured similar occurrences in certain New Hampshire rocks.[7] In 1880 appeared accounts by Irving, and in 1882 by both Irving and Van Hise, of compact brown hornblende originating from diallage.[8] In 1880 C. von John described the alteration of diallage to compact brown hordblende in the olivine gabbro of Bosnia.[9] In 1883 Hj. Sjögren regarded the irregular spots of compact brown hornblende which occur in and around the pyroxene of the wernerite or dipyre-diorite of Bamle in Norway as produced by a molecular rearrangement of the pyroxene substance.[10] In 1884 similar observations were made by myself in certain pyroxenites of the "Cortlandt Series," occurring at Montrose Point on the Hudson River; also in the so-called "black granite" (gabbro) from Addison, Me., and in rocks from the apatite regions of Canada.[11] In the same year (1884)

[1] Geol. Survey, Canada. Report of progress for 1878–79. Appendix G, p. 23.
[2] Outlines of Mineralogy, Geology, etc., London, 1836, vol. 1, p. 153.
[3] Quart. Jour. Geol. Soc. London, vol. 41, 1885, p. 137.
[4] Neues Jahrbuch für Mineral., Beilage-Band 3, 1884, pp. 32, 33.
[5] Geol. Föreningens Stockholm Förhandl., 1876, pp. 151–164; Neues Jahrbuch für Mineral., 1877, p. 99.
[6] Neues Jahrbuch für Mineral., 1877, pp. 133, 240; Am. Jour. Sci., Dec., 1884, p. 464.
[7] The Geology of New Hampshire, vol. 3, 1878, part iv, Mineralogy and Lithology, pp. 57, 206, pl. vii, fig 1.
[8] Geol. Wisconsin, vol. 3, (1880) p. 170; vol, 4, (1882) p. 662. See also Geol. Wisconsin, vol. 1, 1883, p. 221, and Am. Jour. Sci., 3d series, vol. 26. p. 29, 1883.
[9] Grundlinien der Geologie von Bosnien-Herzegovina, Wien, 1880. (Cf. Neues Jahrbuch für Mineral., 1881, vol. 2. Referate, p. 353.)
[10] Geol. Föreningens Stockholm Förhandl., vol. 6, p. 447, 1883. (Cf. Neues Jahrbuch für Mineral. 1884, vol. 1. Referate, p. 81.)
[11] Am. Jour. Sci., 3d series, vol. 28, Oct., 1884, p. 261.

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A. Schenck quotes in his Inaugural Dissertation a statement made by von Lasaulx in 1878, that pyroxene passes first into fibrous and subsequently into compact brown hornblende.[1] Schenck himself observed in the Rimberg diabase from the upper Ruhr Valley that the reverse of this was true, i. e., that the pyroxene passed first into compact brown, and this subsequently into fibrous green hornblende.[2]

The secondary hornblende, so well described and figured by Teall in the Scourie dike, is decidedly compact in its nature,[3] nor is that derived from the paramorphism of the diallage in the Saxon "flaser-gabbros," according to the observations of J. Lehmann, less compact.[4] Such eminent authorities as Lossen[5] and Rosenbusch[6] also allow that there is no doubt that compact basaltic hornblende occasionally results through the direct paramorphism of diallage, or even orthorhombic pyroxene. The chemical composition of the original mineral undoubtedly largely conditions the nature of the resultant product. This is shown by the observations of von John in the Flysch-gabbros of Bosnia, where brown hornblende resulted from dark and green hornblende from pale diallage.[7]

These facts are dwelt upon here somewhat in detail because, as will been seen in the sequel, they have possibly an important bearing on a large part of the Menominee River greenstones.

It is not intended, of course, to imply by the above statements that true parallel growths of primary augite and primary brown hornblende may not occur, as held by both Lossen and Rosenbusch (loc. cit.). Such parallel growths would have the closest possible resemblance to alteration forms, and I can not escape the conviction that the tendency of future studies will be to attribute a secondary origin to more and more of such intergrown brown hornblende.

The derivation of fibrous or actinolitic hornblende, quite identical in all respects with uralite, from compact hornblende (whether brown or green) seems hitherto to have been much neglected. Inostranzeff in 1879 described Russian diorites in which the original hornblende had passed into secondary actinolite, as well as into biotite, chlorite and talc.[8] Becke also, in 1882, mentions uralite formed from both pyroxene and compact, primary hornblende, in the kersantite of the "Niederoesterreichisches Waldviertel."[9]

Descriptions have also been given by myself of compact brown hornblende changing into the green fibrous variety in the Baltimore gabbros.[10]

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[1] Verh. d. naturh. Vereins d. pr. Rheinl. und Westf., 1878, p. 171, pl. IV, fig. 4.

[2] Die Diabase des oberen Ruhrthals. etc., Inaugural-Dissertation. Bonn, 1884, p. 41.

[3] Quart. Jour. Geol. Soc. London, vol. 41, p. 137, 1885, pl. II, fig. 2.

[4] Ueber die Entstehung der altkrystallinischen Schiefergesteine. etc. Bonn, 1884.

[5] Jahrbuch preuss. geol. Landesanstalt für 1884, p. 537, Berlin, 1885.

[6] Mikros. Physiog., 2d ed., vol. 2, 1887, pp. 141, 209.

[7] Ueber kryst. Gest. Bosniens und der Herzegovina in Grundlinien der Geol. von Bosnien-Herzegovina, Wien, 1880 (ref. Neues Jahrbuch für Mineral., 1881, vol. 2. Referate, p. 353).

[8] Studien über metamorphosirte Gesteine im Gouvernement Olenez. Leipzig, 1879 (*cf.* Neues Jahrbuch für Mineral., 1880, vol. 2. Referate, p. 342).

[9] Tschermak's mineral. u. petrog. Mittheil., vol. 5, 1883, pp. 157-159.

[10] Bull. U. S. Geol. Survey, No. 28, p. 45.

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The common alteration of rock-forming hornblende appears to be to chlorite or to epidote, or into an aggregate of both these minerals. This is almost the only change mentioned by Rosenbusch in his most recent works, although in one place he says: "* * * bei Chloritisirung fasert sich die Hornblende aus * * * " etc.[1] That this change of compact to fibrous hornblende is, however, of great importance, the rocks described in the sequel will abundantly prove.

Chloritization.—An admirable exposition of the present state of our knowledge relative to the so-called "chloritic constituent" of the diabases and allied rocks is to be found in the most recent work of Rosenbusch.[2] The secondary hydrous minerals of a green color, whose almost universal presence has brought to this whole class of rocks the general designation "greenstone," owe their existence to the processes known as weathering, rather than to such as may be strictly called metamorphic. There can be but little doubt that they have been formed mainly out of the components of the pyroxene, although these wander so during the process of the alteration that the new products by no means occupy the exact position of the original mineral. It seems possible to distinguish two classes of such secondary substances: First, such as are more or less fibrous in structure, without pleochroism, and have a decided action upon polarized light; and, second, such as are scaly in structure, with pleochroism and so weakly polarizing as to appear isotropic. The first class embraces substances allied to serpentine; the second, those which more or less closely resemble chlorite. In certain cases they have been chemically identified with such indefinite species as delessite, grengesite (Hisinger), seladonite, chlorophæite (Macculloch), epichlorite (Rammelsberg), diabantachronnyn (Liebe),[3] and diabantite (Hawes).[4] All of these substances resemble each other more or less closely in both physical and chemical behavior, and I am inclined to agree with Rosenbusch[5] in preferring the generic term "*chlorite*" or "*chloritic substance*" for them, to even the indefinite designations "*viridite*" of Vogelsang[6] or "*chloropite*" of von Gümbel. In fact Keungott has shown that the formula of diabantachronnyn may be brought quite into accord with that of typical chlorite.[7]

Liebe found the greenish coloring-matter of the dark titanic iron diabases of Voigtland and Frankenwald to be picrolite (serpentine), and it is not unusual to observe the curious vermicular aggregates of circular chlorite scales to which Volger has given the name helminth.[8]

It is well known that the results produced by the weathering of horn-

[1] Mikros. Physiog., 2d ed., vol. 2, 1887, pp. 468, 469.
[2] Ibid., pp. 180–184.
[3] Neues Jahrbuch für Mineral., 1870, p. 2.
[4] Am. Jour. Sci., 3d series, vol. 9, 1875, pp. 454–457; Geol. New Hampshire, vol. 3, part 3; 1878, p. 120.
[5] Mikros. Physiog., 2d ed., vol. 2, 1887, p. 183.
[6] Archives Néerlandaises, vol. 7, 1872; Zeitsch. Deutsch. geol. Gesell., vol. 24, 1872, p. 529.
[7] Neues Jahrbuch für Mineral., 1871, p. 51.
[8] Studien zur Entwickelungsgeschichte der Mineralien, 1854, p. 142.

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blende or mica are, in most instances, quite similar to those just described in the case of pyroxene. Such a change of hornblende may have an equal importance in those greenstones, like a large proportion of those to be considered in this paper, whose bisilicate constituent was originally augite, but which was subsequently changed by a truly metamorphic process (uralitization) to hornblende before the final weathering commenced.

The last result of the action of the atmospheric influences upon the chlorite is, as Rosenbusch long ago showed, to convert it into an aggregate of limonite, carbonate, and quartz.

Epidotization.—The most careful and detailed observations on this process are to be found in the Inaugural Dissertation of Adolf Schenck on the Diabases of the upper Ruhr Valley and their Contact Phenomena.[1] This investigator finds that certain of these diabases are converted into "Epidosites," or aggregates of epidote and either quartz or calcite. He suggests the only three possible hypotheses for the formation of this epidote, viz: (1) That it was formed by the action of the decomposition products of the bisilicate (mainly CaO and Fe_2O_3) upon the feldspar substance; (2) That the reverse was true, i. e., that the decomposition products of the feldspar (mainly Al_2O_3 and CaO) acted upon the pyroxene; (3) That there was a mutual reaction between the decomposition products of both the original constituents. The first of these hypotheses is regarded by the author as the only tenable one for the rocks which he studied, because in all those diabases which contained much epidote the feldspar was remarkably fresh and the pyroxene decomposed, while in those whose feldspar was extensively altered epidote was almost wanting. Observations of the change of feldspar to epidote are cited from the writings of Dathe, Cohen, Rosenbusch, Liebisch, von Lasaulx, Inostranzeff, Zirkel, Michel Lévy, Kühn and Scheilitz; and even more authorities are quoted to show that this same mineral originates from augite, or more commonly from hornblende or uralite. If iron is not at hand, the place of the epidote appears to be taken in the feldspar by zoisite. An excellent example of the origin of epidote as a reactionary rim between the substance of hornblende and plagioclase has been described and figured by myself in the Baltimore gabbros and their derivatives. Here the epidote forms a continuous border around the hornblende, its crystals projecting from it outward into the feldspar[2]

Viridite (chlorite)-Epidote Aggregate.—The simultaneous action of the two last described processes (chloritization and epidotization) in an aluminous pyroxene or hornblende results in the production of an aggregate consisting of sharply defined, pale yellow crystals of epidote, imbedded in a green, scaly mass of chlorite. The appearance of this under the microscope is shown on Pl. XI, fig. 1. The magnesia, together

[1] Die Diabase des oberen Ruhrthals und ihre Contacterscheinungen mit dem Lenneschiefer. Bonn, 1884.

[2] Bull. U. S. Geol. Survey, No. 28, 1886, p. 32. Pl. III, Fig. 2.

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with a proportion of the iron, alumina and silica, have here formed the chlorite; while the lime, instead of becoming a carbonate, as it often does, has become fixed, in combination with the rest of the iron, alumina and silica, as epidote.

Such aggregates have not escaped the notice of petrographical students, though curious mistakes have sometimes arisen as to their true nature and origin.

In 1874 Dathe described this association of chlorite and epidote with great correctness and precision. He says:

When secondary products become abundant and the leek-green viridite increases in amount and distribution, then there are often associated with this light yellow crystals, whose difference from the viridite is very apparent under the microscope. In the progress of my studies, I have recognized these crystals as pistazite.[1]

In 1876 Zirkel described the change of hornblende to an aggregate of epidote, viridite (chlorite) and magnetite, with which, in many instances, more or less calcite was associated.[2]

In the same year, Wichmann, in his paper on the iron rocks of the south shore of Lake Superior, which was not, however, published until 1880,[3] described this chlorite epidote quite correctly in some instances, although he says that it is beyond doubt that the epidote has been formed out of the viridite. In other cases he regards the mineral imbedded in the viridite as a secondary augite, which, as in the last instance, he thinks was formed from the chlorite. He says of this:[4]

The phenomenon of the transformation of viridite into augite has not been observed until recently. It is very interesting to have the fact established that this mineral, after having been changed into another, has finally returned to its former state. * * * Such individuals are only present in viridite and do not seem to occur in any other part of the rock.

George F. Becker in the course of his microscopical studies of the rocks of the Comstock Lode, Nevada, which were either identical with those investigated by Zirkel, or very closely allied to them, found the same change of bisilicates to an aggregate of chlorite and epidote which the latter observer had recorded. Mr. Becker is, however, very positive that the epidote has been developed after and at the expense of the chlorite, instead of simultaneously with it.[5] This he attempts to explain upon chemical grounds.[6] The improbability of Becker's supposition was brought out by Rosenbusch in a review of his work.[7]

In this, as well as in his more recent text-book,[8] Rosenbusch clearly

[1] Wenn die Neubildungsproducte sich im Gestein häufen, wenn der lauchgrüne Viridit [Chlorit] an Masse und Verbreitung zunimmt, stellen sich oftmals neben letzteren lichtgelbliche Gebilde ein, deren Verschiedenheit vom Viridit bei mikroskopischer Betrachtung sofort in die Augen springt. Im Verlauf der Untersuchung wurden diese Gebilde als Pistazit erkannt. Mikroskopische Untersuchungen über Diabase. Zeitsch. Deutsch. geol. Gesell., vol. 26, 1874, p. 16.

[2] Microscopical Petrography, Washington, 1876, p. 66, Pl. III, Figs. 2 and 3.

[3] Geol. Wisconsin, vol. 3, 1880, pp. 600–656.

[4] Ibid., pp. 623, 624.

[5] The Geology of the Comstock Lode. Monograph U. S. Geol. Survey, vol. 3, p. 76.

[6] Ibid., pp. 211–214.

[7] Neues Jahrbuch für Mineral., 1884, vol. 2. Referate, p. 189.

[8] Mikros. Physiog., 2d ed., vol. 2, pp. 108, 183.

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shows that the true deviation of the chlorite-epidote aggregate is to be found in a division of the bisilicates out of which it is formed, the magnesia passing into the chlorite and the calcium and ferric iron into the epidote. The triclinic feldspar may often materially assist in this formation by furnishing the necessary lime.

Nor is this mistake of Mr. Becker's a new one. Francke in 1875 described the same mineral association and gave the same explanation for it;[1] while in 1880 Schauf,[2] in 1882 Riemann,[3] and in 1884 Schenck corroborated the observation, although both Schauf and Schenck[4] raised unanswerable chemical objections to the derivation of the epidote from the chlorite.

Saussuritization.—The hard, compact, whitish or greenish substance, without luster or cleavage, which forms one of the two main components of the certain coarse gabbros or euphotides, was called by H. B. Saussure, in 1780, "jade."[5] In 1806 Th. Saussure named this mineral, in honor of his father, "saussurite,[6] but its true nature continued for over half a century to elude all mineralogists. As long as chemical analysis was the only means with which it could be studied, any satisfactory solution of the riddle seemed to be impossible. Such investigators as vom Rath,[7] Klaproth,[8] T. Sterry Hunt,[9] and many others obtained the most diverse results; the composition in some cases approaching that of zoisite, in others that of garnet, scapolite, or feldspar. In 1866, Zirkel remarked, at length, upon the extremely imperfect state of knowledge regarding this geologically important mineral.[10]

It remained for the microscope to disclose the composite nature of saussurite as well as to point out the true significance of its origin and occurrence.

Hagge was the first to correctly describe saussurite as an aggregate of colorless or greenish crystal needles, prisms or grains, irregularly scattered through a colorless, glassy-looking matrix.[11] He, however, retained the name saussurite for the included grains, and did not attempt to determine their mineral nature. Hagge also clearly recognized that in all cases observed by him the saussurite was a product of the alteration of feldspar, and that the passage from one mineral to the other was a gradual one which the microscope could easily follow.[12] These results were

[1] Studien über Corillerengesteine. Inaugural-Dissertation. Leipzig, 1875.
[2] Verhl. d. nat. Vereins d. pr. Rheinl. u. Westf., 1880, p. 6.
[3] Ibid., 1882, p. 256.
[4] Inaugural-Dissertation. Bonn, 1884, p. 45.
[5] Voyages dans les Alpes, vol. 1, Neuchâtel, 1779, p. 83.
[6] Annales de chimie et de physique, 3d series, vol. 16, p. 469.
[7] Poggendorff Annalen, vol. 95, 1855, p. 555.
[8] Beiträge, vol. 4, p. 271.
[9] Am. Jour. Sci., 2d series, vol. 27, 1859, pp. 336–349.
[10] Lehrbuch der Petrographie, vol. 1, p. 27; vol. 2, p. 110, 1866.
[11] Mikroskopische Untersuchungen über Gabbro and verwandte Gesteine. Kiel, 1871. On p. 51 he says: "Der Saussurit besteht aus kleinen Krystallnadeln, Prismen und Körnern, die farblos oder blassgrün sind und regellos in einer wie ein farbloses Glas aussehenden Grundmasse, die auch vielfach klare Spalten in dem Saussurit bildet, verthielt liegen."
[12] Ibid., pp. 35 and 51.

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quoted by Zirkel in his text-book, published in 1873.[1] The conclusion that saussurite was "an aggregate and probably the end product of a molecular rearrangement in the feldspar" was also reached by Rosenbusch in the same year.[2] In 1878 Becke showed that the saussurite of certain Grecian rocks was largely zoisite;[3] and in 1883 appeared the important paper by Cathrein upon this subject.[4] This author draws from his work the following six conclusions as to the nature of saussurite.

(1) The so-called saussurite, far from being a homogeneous mineral, is an aggregate of plagioclase, rarely orthoclase, with zoisite. Actinolite, chlorite, and other minerals may also occur as accessories.

(2) The chemical composition of saussurite resembles most that of the lime soda feldspars; it, however, contains less silica, more lime, and has a higher specific gravity.

(3) The proportions of the saussurite elements can be calculated from the amounts of alkalies, lime, and iron, if we know the species of the original feldspar.

(4) This proportion can also generally be calculated, even when this last factor is unknown, by a consideration of the relative difference of silica, alumina and lime in zoisite and anorthite.

(5) Saussurite is a product of the metamorphism of feldspar through an exchange of silica and alkali for lime, iron and water.

(6) The epidotization of feldspar is genetically the same process as saussuritization and differs only in the larger proportion of iron required.

H. Reusch considered the saussurite which composed a large part of the Bergen gabbros as partly epidote, partly zoisite.[5] Traube found the structure and composition of the saussurite occurring in the gabbros of Lower Silesia to be like that described by Cathrein,[6] while Brögger mentions neither epidote nor zoisite, but regards some member of the scapolite family as probably present in the saussurites studied by him.[7] Paul Michael has recently investigated the saussurite-gabbros of the Fichtelgebirge in Bavaria and concludes that two main types of saussurite occur there. One of these consists mainly of zoisite, with more or less alkaline feldspar, and the other is composed of a pale lime alumina garnet together with serpentine.[8]

J. Lehmann[9] and Lossen[10] were the first to recognize in the saussuritization of feldspar a result of dynamic or regional metamorphism—an idea which Rosenbusch has lately more clearly developed and elabo-

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[1] Die mikroskopische Beschaffenheit der Mineralien und Gesteine. Leipzig, 1873, p. 143.

[2] Die petrographisch wichtigen Mineralien, 1873, p. 356.

[3] Tschermak's mineral. u. petrog. Mittheil., vol. 1, 1878, p. 247.

[4] Zeitschr. Kryst., vol. 7, 1883, p. 234.

[5] Die fossilien-führenden krystallinischen Schiefer von Bergen in Norwegen. German translation by Baldauf, 1883, p. 40.

[6] Beiträge zur Kenntniss der Gabbros, Amphibolite und Serpentine des nieder-schlesischen Gebirges. Inaug.-Dissert., 1884, pp. 7, 20.

[7] Nyt Mag. for Naturvidenskaberne, vol. 28, 1884, p. 253.

[8] Neues Jahrbuch für Mineral., 1888, vol. 1, pp. 36–41.

[9] Untersuchungen über die Entstehung der altkrystallinischen Schiefergesteine, etc. Bonn, 1884, pp. 197, 199.

[10] Jahrbuch k. preuss. geol. Landesanstalt für——p.——

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rated.[1] This last-named authority shows that the new mineral developed in the feldspar is by no means always of necessity zoisite or epidote. It may also be garnet, or a mineral of the scapolite family. He remarks:[2]

> The sum total of these new products, which are certainly not produced by normal weathering, but are due to a metamorphic process, we designate as the *saussuritization* of feldspar.[3]

Michel-Lévy was the first to show that the so-called "spotted-gabbro (gefleckter Gabbro) of Brögger and Reusch was a mixture of amphibole and wernerite;[4] and Sjögren has since demonstrated that the latter mineral is secondary to feldspar, and the first to pyroxene. Fouqué and Michel-Lévy tried the interesting experiment of fusing this rock, and obtained therefrom an aggregate of pyroxene and labradorite.[6]

Formation of the Albite Mosaic.—Analogous and closely related to the saussuritization of feldspar are cases where, in the process of its alteration by metamorphism, the lime is more or less completely removed or crystallized as calcite, instead of forming a calcium silicate. In such instances the alkaline portion of the plagioclase molecule crystallizes in the form of a finely granular aggregate, or mosaic of limpid grains (albite). These may be wholly devoid of twinning lamellæ and often closely resemble quartz, with which they are not infrequently associated. Of course such mosaics are connected by every stage of transition with saussurite, according as more or less of the lime has remained as a calcium silicate (zoisite or epidote).

Such a granulation of the feldspar substance has already been alluded to under the head of microstructural metamorphism; but, inasmuch as a complete solution and recrystallization of clear feldspar substance often takes place, it belongs quite as much to this division of the subject. The geological significance of this method of feldspar alteration, especially in certain basic eruptive rocks like diabase, has been most persistently emphasized by Lossen. He has shown how it may result in the total obliteration of the original and characteristic rock-structure, and how, therefore, it may prove most misleading, unless its nature and origin are clearly understood.[7] J. Lehmann,[9] Teall,[8] and others have also observed and commented on such a secondary feldspar mosaic.

Sericitization.—The soft, unctuous mineral characteristic of so many slates and schists was formerly regarded as talc. This gave rise to the

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[1] Mikros. Physiog., 2d ed., vol. 2, 1886, p. 164.

[2] Ibid., p. 137.

[3] "Die Gesammtheit dieser Neubildungen, die sicher keine Art der normaler Verwitterung, sondern ein metamorpher Vorgang ist, bezeichnet man als die *Saussuritisirung* des Feldspaths."

[4] Bull. Soc. Minéral. de France, vol. 1, 1878, pp. 43, 79.

[5] Geol. Föreningens Stockholm Förhandl., vol. 6, 1883, p. 447 (Neues Jahrbuch für Mineral., 1884, vol. 1, referate p. 81).

[6] Bull. Soc. Minéral. de France, vol 2, 1879, p. 105.

[7] Jahrbuch preuss. geol. Landesanstalt für 1883, p. 640 Pl. 29; ibid., 1884, pp. 525–530, Pl. XXIX, Figs. 2 and 4.

[8] Untersuchungen über die Entstehung der altkrystallinischen Schiefergesteine, etc., 1884, p. 207.

[9] Quart. Jour. Geol. Soc. London, vol. 41, 1885, p. 139.

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common designation "soapstone" or "talcose slates," which was used very early in America by Amos Eaton.[1] As early as 1819, however, Prof. Chester Dewey, of Williams College, made the statement that he was able to detect very little magnesia in the specimens which he examined, while alumina was abundant. He therefore preferred to call these rocks micaceous slates.[2]

In Europe, slates of this kind were first studied from the Taunus, where they were usually regarded as talcose until 1847, when Sandberger made the same discovery that Dewey had made with regard to the American rocks.[3] List subsequently studied more carefully this micaceous constituent of the Taunus schists, and named it, on account of its silky luster, "Sericite."[4] Scharff attacked the conclusions of List and considered sericite to be only a mixture,[5] while Lossen vigorously defended the individuality of the mineral.[6]

The sericite was soon identified by many investigators in the rocks of many regions.[7] Prof. Dana united it with the species margarodite and damourite in the group of hydro-micas and called this class of slates the hydro-mica slates. Of these so-called hydro-micas Prof. Dana says:

> The following species [margarodite, damourite, parophite, sericite, sericite schist, groppite, euphyllite, cookeite, voigtite, roscoelite,] are mica-like in cleavage and aspect, but talc-like in wanting elasticity, in greasy feel, and in pearly luster. They are sometimes brittle. Common mica, muscovite, readily becomes hydrated on exposure; but hydrous micas are not all a result of alteration. Hydro-mica schists form extensive rock-formations, equal to those of the ordinary mica-schists.[8]

In 1880 Laspeyres made a very thorough examination of sericite and showed conclusively its identity with muscovite.[9] It differs from the ordinary form of this species only in its compact structure and in its geological significance; but, since both of these are characteristics, there is a decided advantage in retaining the name sericite, especially in petrography, to designate a peculiar form and occurrence of muscovite.

The alteration of orthoclase into kaolin or clay was very early known.[10] The corresponding change of the same feldspar into mica was first observed by Haidinger in 1841,[11] but was subsequently found to be not

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[1] Index to the Geology of the Northern States, pp. 147, 174, 286.

[2] Am. Jour. Sci. 1st series, vol. 1. 1819, p. 310. Thus the discovery, usually attributed to Sandberger, was anticipated in America by twenty-eight years. Cf. Dana's Manual of Geology, 3d ed., p. 72.

[3] Uebersicht d. geol. Verhältnisse d. Herzogth. Nassau, 1847, p. 94.

[4] Jahrb. d. Vereins f. Naturkunde im Herzogth. Nassau, vol. 6, 1850, p. 126; vol. 7, 1851, p. 266; vol. 8, 1852, p. 128; Annalen Chem. und Pharm., vol. 81, 1852, p. 181.

[5] Neues Jahrbuch für Mineral., 1868, p. 309; ibid., 1874, p. 271.

[6] Zeitschr. Deutsch. mineral. geol. Gessell., vol. 19, 1867, p. 509; vol. 21, 1869, p. 281.

[7] e. g., by Pichler in the Tyrol. Neues Jahrbuch für Mineral., 1871, p. 56; by Törnebohm in Sweden, Neues Jahrbuch für Mineral., 1874, p. 141; by von Lasaulx in the Ardennes; by Credner in Saxony and by Wichmann in the Lake Superior rocks.

[8] Manual of Mineralogy and Petrography. 4th ed. New York, 1887, p. 335.

[9] Zeitschr. Kryst., vol. 4, 1880, pp. 244–256.

[10] Blum: Pseudomorphosen d. Mineralreiches, 1843, p. 72.

[11] Abh. d. k. böhm. Gesell. d. Wissenschaft, 1841, p. 4. Blum: Pseudomorphosen, Nachtr., I, 1847, p. 28.

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uncommon. Since rocks have been studied with the microscope, the change of potash feldspar to muscovite or sericite has been found to possess a wide significance, especially in dynamic metamorphism.

There seems every reason to believe that sericite always originates from potash feldspar and not from other micas. Its constant and very intimate association with quartz shows, as first pointed out by Laspeyres,[1] that it was derived from an acid silicate.

Any rocks, therefore, whether sedimentary or massive, which contain orthoclase, may give rise to sericite; but its formation, in any case would seem to require the action of some great dynamic force. The close relation between dislocation and mica formation, so clearly illustrated by J. Lehmann,[2] is in an eminent degree applicable to sericite. It is now a well known and oft-recorded fact that in any rock mass, where the strains and stresses have been the most intense, there the micaceous minerals are most abundant; and if the rocks are orthoclastic these will be largely sericite. Sericitization is therefore a phenomenon of dynamic metamorphism. It is in a way, as Lehmann says, a retrogressive metamorphic process, since feldspar is by it not formed, but destroyed. It is also the most extreme manifestation of dynamic action in orthoclase rocks and may produce the same result—a sericite schist—from a clastic arkose on the one hand, and from a massive granite or quartz-porphyry on the other.[3]

In an admirable paper on the paragenesis of certain ore deposits, A. von Groddeck has shown that the rocks, heretofore considered as talcose, which occur near Holzappel and Werlau on the Rhine, at Mitterberg in Salzburg and at Agordo in the Venetian Alps, are in reality sericite schists. These he considers to represent the extreme phase of metamorphism, in some cases of an eruptive rock (diabase), and in other cases of a normal clay state or graywacke.[4] It seems most probable that these rocks owe their origin to dynamic agencies, with which the deposition of the ore also stands in close relationship.

The alteration of the feldspathic groundmass of quartz porphyries to muscovite or sericite, especially where these have been rendered schistose by pressure, is now well known. In this way porphyroids may be derived from massive eruptive rocks. In the more massive quartz porphyries studied by C. Schmidt from the central Alps (Windgällen), sericite is met with as an occasional pseudomorph after the feldspar, but in the schistose porphyries derived from the latter by pressure and stretching, this mineral is much more abundant; so abundant, indeed, as, in some instances, to make up, along with quartz, the whole mass of the rock.[5]

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[1] Zeitschr. Kryst., vol. 4, 1880, p. —.

[2] Untersuchungen über die Entstehung der altkrystallinischen Schiefergesteine. Bonn, 1884. Cap. IX. Druckschieferung und Glimmerbildung, p. 136.

[3] Ibid., p. 101.

[4] Zur Kenntniss einiger Sericitgesteine, welche neben und in Erzlagerstätten auftreten. Neues Jahrbuch für Mineral., Beilage-Band 2, 1883, pp. 72–138.

[5] Neues Jahrbuch für Mineral., Beilage-Band 4, 1886, p. 428.

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Alterations of titanic iron.—The element titanium exists in unaltered diabases almost exclusively in combination with iron as ilmenite or as titaniferous magnetite. In the processes of metamorphism, however, various other titanium compounds are formed. The most common phase of this change consists in the development of a gray rim around the the ilmenite grains. This substance is also often seen along the rhombohedral cleavage cracks of the ilmenite, giving rise to the well known gridiron structure so often figured.[1] There can be no doubt that this gray material is an alteration product of the ilmenite, although Gümbel, who gave it its name, *leucoxene*, regarded it as a parallel growth of another mineral.[2] Much difference of opinion formerly prevailed in regard to the chemical nature of the leucoxene. Zirkel at first regarded it as iron carbonate,[3] Cohen as titanic oxide,[4] Rosenbusch as anatase.[5] Gümbel regarded it as probably a titanosilicate, while both Fouqué[6] and Michel-Lévy[7] thought that it was a form of sphene. The identity of both leucoxene and titano-morphite (another similar substance described by von Lasaulx around the rutile of an amphibolite from Lampersdorf in Silesia)[8] with titanite or sphene was first conclusively proved by A. Cathrein in 1882.[9]

The frequent passage of the dull gray leucoxene rim into clearly defined aggregates and crystals of sphene is mentioned by Cathrein,[10] and the origin of sphene by the alteration of ilmenite is also described by W. C. Brögger.[11] Fine examples of this origin for sphene are also described and figured in the sequel.

Anatase has been described as an alteration product of ilmenite, by Diller.[12]

The rutile needles frequently seen about ilmenite, either with or without leucoxene, are regarded by Cathrein as an original intergrowth of this mineral with the ilmenite.[13] Further reference will be made hereafter to needles of this character occurring in some of the Menominee greenstones.

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[1] Cf. Vallée de la Poussin et Renard: Roches plutoniennes de la Belgique, etc., 1874, Pl. VI, Figs 31 and 32.

[2] Palæolithische Eruptivgesteine des Fichtelgebriges, Munich, 1874, p. 35.

[3] Mikroskopische Beschaffenheit d. Min. u. Gest., 1873, p. 409.

[4] Erläuternde Bemerkungen z. d. Routenkarte, etc., 1875, p. 55.

[5] Mikros. Physiog., 1st ed., vol. 2, 1877, p. 336.

[6] Cours de Collège de France, 1877.

[7] Bull. Soc. Géol. France, 3d series, vol. 6, 1878, p. 103.

[8] Neues Jahrbuch für Mineral., 1879, p. 568.

[9] Zeitschr. Kryst. u. Min., vol. 6, 1882, p. 244.

[10] Ibid.

[11] Nyt Mag. for Naturvidenskaberne, vol. 27, 1884, p. 359.

[12] Neues Jahrbuch für Mineral., 1883, vol. 1, p. 193.

[13] Zeitschr. Kryst. u. Min., vol. 6, p. 256.

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CHAPTER II.

GREENSTONE BELTS OF THE MENOMINEE IRON DISTRICT.

INTRODUCTORY AND HISTORICAL.

The exact geographical position of the two greenstone-schist areas of the Menominee region are fully indicated in the explanatory and historical note by Prof. Irving at the beginning of this memoir and upon the accompanying geological map of this district. (Pl. II). The same note explains and discusses the different views which have been held by various geologists in regard to the stratigraphical position of these greenstone schists in the general succession of the stratiform rocks of the Menominee region.

A brief mention of the opinions which have already been published regarding the petrographical character of these greenstone schists is, however, desirable.

The first attempt to describe the Menominee greenstones and greenstone schists lithologically was made by Hermann Credner in 1869, from observations collected while he was acting as assistant to Prof. Pumpelly on a survey for the Portage Lake and Lake Superior Ship Canal, during the years 1867–'68.[1] In his first paper entitled *Die vorsilurischen Gebilde der oberen Halbinsel von Michigan in Nord-Amerika*,[2] Credner gives a section of the strata of the Menominee Iron Region, commencing with the oldest member, from which the following is abbreviated:

	Feet.
a. Quartzite	8,000
b. Crystalline dolomitic limestone	3,500
c. Red Iron ore	600–1,000
d. Chlorite schist	1,000–1,500
e. Clay slate	8,500
f. Chlorite schist with diorite	1,200–1,400
g, h, i, k. Talc schist	150
l. Dioritic series	2,300
m. Talcose clay slate	1,500

The members *f* and *l* are evidently parts of the same formation, in which the beds *g*, *h*, *i*, and *k* are interstratified. In his description of *f*, Credner says:

In the upper horizon of this series there occur beds of fine and coarse grained diorite and aphanite, varying in thickness from ten feet to several hundred. These

[1] See Geology of Michigan, vol. 1, 1873, p. 157, note.

[2] Zeitschr. Deutsch. geol. Gesell., vol. 21, 1869, pp. 516–554.

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rocks consist mainly of dark green hornblende and white or pale green oligoclase, with which granular or scaly chlorite is often associated. Crystals of pyrite and magnetite are also frequent. Indications of a lamellar parting are frequent, while rectangular jointing is rare.[1]

In the same article, in speaking of the member *l*, the author says:[2]

Dioritic series 2,300 feet in thickness. Mainly a fine grained or aphanitic, rarely a coarsely crystalline aggregate of the constituents of diorite. All contain crystals of pyrite; the aphanite contains veins of calcite and quartz.[3]

In a second article entitled *Ueber nordamerikanische Schieferporphyroide*, which also deals with certain rocks exposed on the Menominee River,[4] Credner unites his beds *f* and *l* as "chlorite schist alternating with intercalated diabase;" while his *g*, *h*, *i*, and *k* are described as a series of "porphyroid-schists," 300 feet in thickness, between two beds of diabase.

In the year 1869 the geological survey of Michigan was inaugurated with the iron-bearing formations of the Upper Peninsula, in charge of Maj. T. B. Brooks. The results of his labors appeared in 1873,[5] accompanied by two appendices, containing special petrographical descriptions of the rocks collected by Julien,[6] and Wright.[7] Several of the Menominee greenstones, both massive and schistose, come within these descriptions, but the descriptions are for the most part vague; as, for instance "diorite," "dioritic schist," "porphyritic diorite," etc.

In 1874 Major Brooks continued his studies of the Menominee region under the auspices of the Wisconsin Geological Survey. The results of this work appeared in 1879[8] and contained much more elaborate and accurate determinations of the greenstones and greenstone schists. Major Brooks gives a diagram[9] to illustrate his general views of the observed transitions of greenstones (believed to be mostly metamorphosed sediments) into related rocks. Dr. Wichmann, who furnished the systematic petrographical descriptions of these rocks in Brooks's report,[10] however, regarded these rocks as for the most part eruptive and to a large extent as derived from diabase. Special reference will be made to the descriptions of Wichmann and others who have worked

[1] Zeitschr. Deutsch. geol. Gesell., vol. 21, 1869, p. 528.

[2] Im oberen Horizonte dieser Schichtenreihe treten von 10 bis mehrere hundert Fuss mächtige Einlagerungen von fein- bis grobkörnigem Diorit sowie von Aphanit auf. Sie bestehen vorwaltend aus dunkelgrüner Hornblende und weissem oder hellgrünem Oligoklas, wozu sich an manchen Punkten viel körnig-schuppiger Chlorit gesellt. Einsprenglinge von Schwefelkies und Magneteisenstein sind in ihnen häufig. Andeutung von plattenförmiger Absonderung ist gewöhnlich, quarderförmige Absonderung selten.

[3] Ibid., p. 529.

[4] Dioritische Gesteinsreihe von 2,300′ Mächtigkeit. Vorwaltend ein feinkörniges oder aphanitisches, seltener ein grobkrystallinisches Gemenge der Bestandtheile des Diorites, alle mit Schwefelkies ein ein sprenglingen, die Aphanite mit Schnüren von Kalkspath und Quarz.

[5] Neues Jahrbuch für Mineral., 1870, pp. 970–984.

[6] Geol. Survey Michigan, vol. 1, Upper Peninsula. Part I. Iron-bearing rock, by T. B. Brooks. 1873.

[7] Ibid., vol. 2, 1873. Appendix A. Lithological descriptions, etc., of 259 specimens of the Huronian and Laurentian of the Upper Peninsula, by A. A. Julien, pp. 1–197.

[8] Ibid., vol. 2, 1873. Appendix C. Microscopic determinations and descriptions of 78 specimens of Huronian rocks and ores, by C. E. Wright, pp. 213–231.

[9] Geol. Wisconsin, Vol. 3, 1873–1879. The Geology of the Menominee Iron Region, Oconto County, by T. B. Brooks, pp. 429–663. Ibid., Geol. Menominee Region by C. E. Wright, pp. 665–741.

[10] Ibid., 519. [11] Ibid., pp. 600–656.

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upon the petrography of the Menominee greenstones in the course of the following chapters of this work.

All observers seem to be agreed that the association of the massive greenstones with those which are more or less perfectly schistose is an extremely intimate one. Even Major Brooks, in spite of his idea that most of the greenstones are altered sediments, is constantly suggesting the possibility of a mechanical origin for the intercalated schistose layers. He says[1] of the Twin Falls exposure:

> This slaty material may be simply a compacted form of the pulverized greenstone produced at the time of fissuring.

Again,[2] in speaking of the Commonwealth and Eagle Mine rocks:

> It will be observed that these rocks have some resemblance to *aa*, but it is believed that they are associated schistose and altered varieties of the great greenstone bed XVIII, so extensively developed to the north and east.

He says[3] also:

> An unevenly splitting, gray-green schist associated with greenstones and apparently derived from them by alteration of the amphibole, is included in this family [chlorite schist], although its origin and associations are widely different from the above.

Again:[4]

> One of the largest, most generally distributed, and at the same time, obscure varieties embraces those chloritic rocks that are associated with greenstones.

Dr. C. Rominger, in his Report on the Geology of the Menominee Iron Region,[5] is equally impressed with the close association of the massive and schistose varieties of the greenstones. Like Brooks, he regards them as of sedimentary origin, and thinks that the massive portions are the result of extreme metamorphism, having recrystallized from a partially fused state.

There seem to be only three different ways of explaining the facts as they are plainly and abundantly manifested at each of the several points examined on the Menominee River.

We may suppose, as did Foster and Whitney, Whittlesey and Credner, that the schistose portions of the rocks exposed at these several points are more or less perfectly metamorphosed sedimentary material, while the more massive portions represent intercalated beds of eruptive origin.

We may imagine, on the other hand, as did Rominger and Brooks, that all of these rocks, including the most schistose and the most massive phases, are probably altered sedimentaries; supposing, with Rominger, that the more massive kinds are merely the same sedimentary material fused by the intensity of the metamorphosing action so as to lose all trace of the original stratification; or admitting, with Brooks, the possibility, though great improbability, that some of the more massive phases like the gabbro of Sturgeon Falls, are of eruptive origin.

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[1] Geol. Wisconsin, vol. 3, 1873–1879. The Geology of the Menominee Iron Region, Ocorets County, by T. B. Brooks, p. 477.

[2] Ibid., p. 484.

[3] Ibid., p. 516.

[4] Ibid., p. 518.

[5] Geol. Michigan, vol. 4, 1881, p. 209.

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Finally, we may imagine that all phases seen at these several places represent material of eruptive origin whose stratiform structure is due to secondary dynamic agencies. This last view has heretofore been advanced only by Irving, who, however, has presented it very briefly, and without descriptions or petrographic proof.[1]

It is the aim of the present portion of this paper to set forth all the evidence that a careful examination of these rocks can furnish as to which of these three views best explains their true origin and mutual relations. This material will first be presented in the form of a detailed description of each of the five localities selected for this purpose on the Menominee River (see Pl. II). The general results thus secured will be summarized, in connection with those obtained elsewhere, in Chap. VI. The Menominee localities will be treated of in regular order, commencing with the one farthest down the river, Sturgeon Falls.

STURGEON FALLS.

Kinds of rock.—This exposure is situated a short distance below the mouth of the Sturgeon River, in Sec. 27, T. 39 N., R. 29 W., Michigan. Its general topography may be seen from the accompanying map (Pl. III), which is copied from Pl. I, in Major Brooks's report with double his linear scale. Only the rocks exposed on the eastern or Michigan side of the river were examined; but those opposite could be seen to be of the same character.

The barrier which here forms the falls consists of two belts of massive rock, *f* and *h*, between which are softer schists, *g*. These are also intercepted by a harder and more massive band.

The massive rock is light in color and of a comparatively coarse grain. It is quite elaborately described in Major Brooks's report,[2] and designated on the authority of Wapler, Rutley, and Pumpelly as a gabbro. Julien also examined this rock, but seems to have mistaken the diallage for hornblende, and the brown pleochroic hornblende for biotite. Rutley's opinion is given with hesitation. Pumpelly's description is brief and accurate. He says:[3]

> Saussurite-gabbro (or hornblende gabbro): contains saussurite, diallage, hornblende. Identical under the microscope with the coarser crystalline rock of Upper Quinnesec Falls.

This rock was considered serpentine by Foster and Whitney[4] and was provisionally named "porphyritic, speckled diorite" by Brooks, who separated it as his Bed XV of the Huronian.

The massive occurrence at *f* is represented by Nos. 11154, 11155, and 11162; that at *h* by Nos. 11167, 11168, 11169, and 11170. Nos. 11156–11161, and 11163–11166 were collected from the softer schistose bands at *g*.

These rocks are particularly noteworthy as being the only ones discovered on the Menominee River which contained any trace of pyroxene.

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[1] Fifth Annual Report U. S. Geol. Survey, p. 190. [2] Geol. Wisconsin, vol. 3, pp. 458–563. [3] Ibid., p. 564. [4] Report on the Geol. Lake Superior Land District Plate 2, p. 25.

We shall find that they agree perfectly with Pumpelly's description above cited, the hornblende being in part secondary, and they are hence to be designated as saussurite-gabbro. The least altered specimens were found at *h* (Nos. 11167–11170). The rock at *f*, although essentially the same as at *h*, is more changed and somewhat schistose along certain bands, while some of the specimens found at *g* were clearly once the same as the others, but now represent a third and much more advanced stage of alteration. I shall first describe these three stages of the undoubted gabbro, and then trace their relation to the intermediate schists.

Saussurite-gabbro (*first stage*).—The color of this rock in the hand. specimen is rather light. On a fresh fracture it shows a finely mottled structure of white and dark greenish-gray. Examined with a pocket-lens, the mottling is seen to be due to two minerals. One of these is opaque white, sometimes tinged with green, and only rarely exhibits the glistening cleavage surface of feldspar. The darker mineral has a brownish color and almost a metallic luster on its cleavage surface. It is, however, always tinged with green on account of incipient alteration.

No other constituents are microscopically visible. The structure of the rock is irregularly granular. The grain is as a rule moderately fine but is subject to sudden local variation which develops comparatively coarse-grained patches in the main mass.

Of this freshest type of the gabbro four thin sections were studied, viz, 11167, 11167[a], 11168 and 11170. All show profound alteration in the original constituents, due to dynamic processes. These are, however, most intense in No. 11167, which has been subjected to such great pressure as to present a transition form to the second stage of this gabbro. Nos. 11167[a], 11168, and 11170, are practically identical and may be described together.

Under the microscope this rock is seen to be composed of plagioclase, almost wholly altered to a gray and opaque saussurite; diallage, of a very light gray color; hornblende, partly original, partly secondary, and a little titanic iron (ilmenite). Certain alteration products, like quartz, calcite, and a colorless chlorite, are also present in varying quantity.

The feldspar has no crystal form of its own (i. e., it is allotriomorphous, in the sense of Rosenbusch). It seems to have crystallized simultaneously with the diallage, or if anything later. It is hardly ever so unaltered as to present its original twinning-lamellæ, but when this is the case the high extinction angles and brilliant interference colors observed indicate a basic feldspar. No further determinations could be made on this mineral because of its almost complete alteration to a dull opaque white saussurite. Even in the thinnest sections this substance remains opaque for the lower powers of the microscope, being composed of such fine grains that it must be highly magnified before it can be resolved. Under higher powers, however, it is seen to be made

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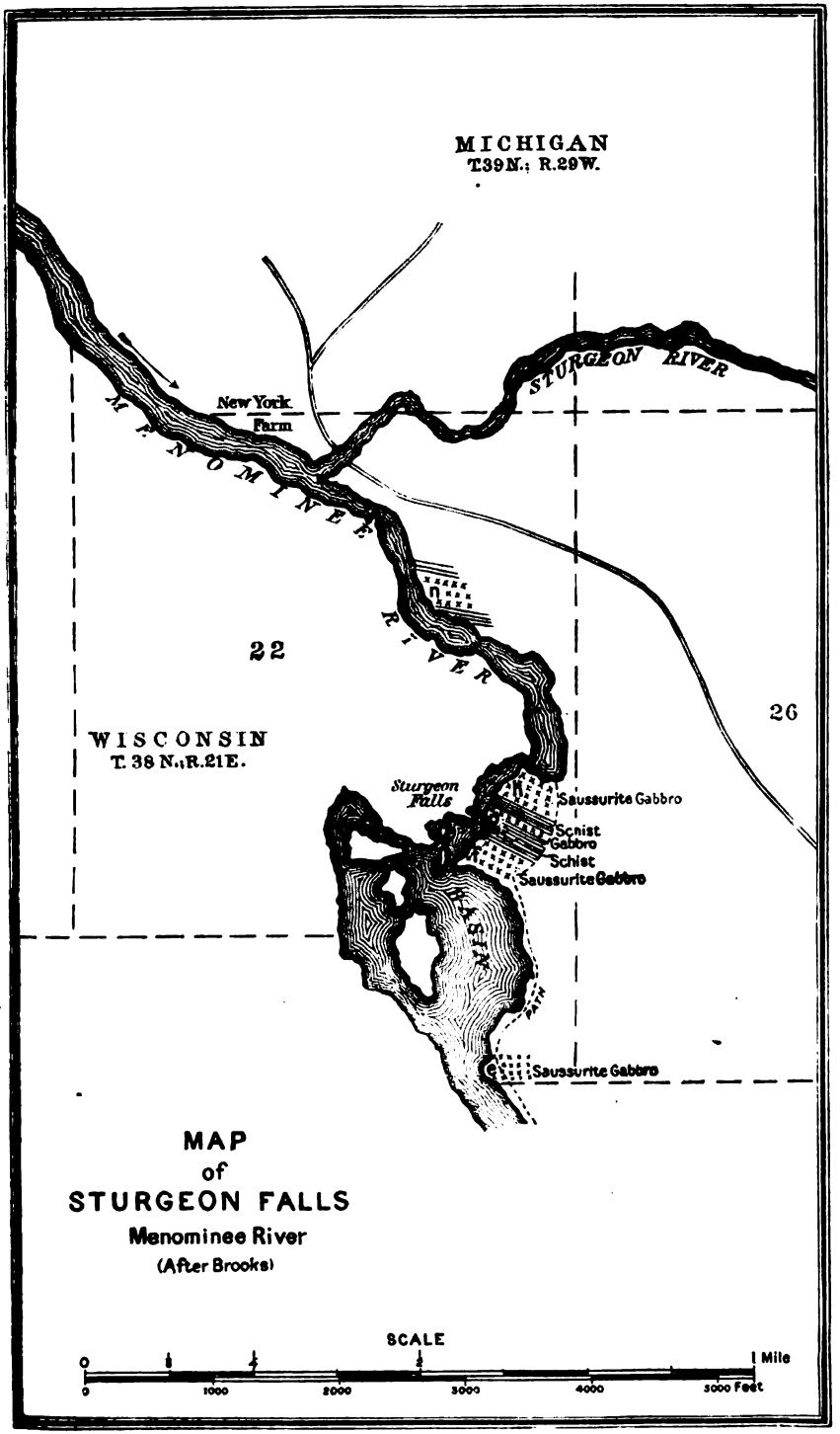

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up of small zoisite grains, embedded in a clearer matrix, which is probably albite.[1]

This saussurite substance is traversed in all directions by lighter—sometimes quite clear and transparent—veins, which are composed largely of secondary albite. This in at least one instance (No. 11168) shows the characteristic twinning striation of plagioclase (see Fig. 4). In other cases, however, these veins appear to be composed of quartz or chlorite (see Pl. VIII, fig. 1).

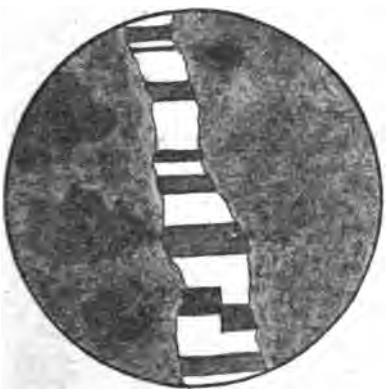

FIG. 4.—Veins filled with secondary albite in the altered gabbro of Sturgeon Falls (No. 11168). Represented in polarized light in order to show the twinning striæ. Magnified 350 diameters.

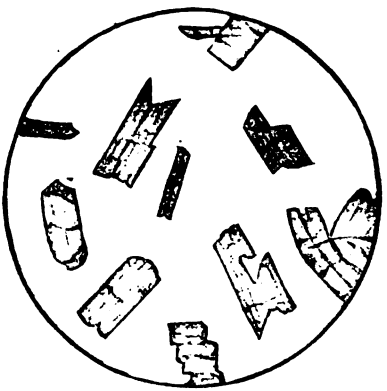

FIG. 5.—Zoisite crystals in a coarse saussurite from the altered gabbro of Sturgeon Falls Magnified 180 diameters.

In certain cases, notably in section No. 11167, the saussurite aggregate is coarser and the zoisite plainly visible and easily determinable.

Fig. 5 shows characteristic forms of this mineral. Its crystals are always without terminal planes, but they have a perfectly developed cleavage parallel to their vertical axis and a cross-jointing. Between crossed nicols they are seen to be twinned, sometimes polysynthetically, like albite. The zoisite is itself colorless, with a high index of refraction, but a weak double refraction; the interference colors are therefore dull, either gray or bluish, and sometimes a deep ultramarine. The extinction is parallel to the cleavage lines.

One unusually large crystal of zoisite, represented in Fig. 6, exhibits all of these characteristics, and also, when examined in converged polarized light, it gives a biaxial interference figure with the plane of the optic axes perpendicular to the cleavage. (Fig. 6.)

[1] Zeitschr. Kryst. u. Min., vol. 7, pp. 234–249. Cathrein, in this article, calculates a number of saussurite analyses to show the relative amounts of feldspar and zoisite or epidote present. He seems to think that the feldspar left after subtracting the zoisite gives the original constitution of the mineral before its change to saussurite, and attributes the alteration to the addition of CaO and Al_2O_3 and loss of silica and alkalies (p. 243). Another hypothesis would be that the original feldspar was much more basic (i. e., contained more CaO, Al_2O_3 and less SiO_2 and Na_2O) than the one now forming the matrix of the saussurite, and that this compound broke up without material chemical change into two compounds, one a more acid plagioclase, like albite or oligoclase and the other zoisite, which would contain what CaO and superfluous Al_2O_3 was left after the change. A similar separation of one mineral into two has been traced by Profs. J. Brush and E. S. Dana in the alteration of spodumene into a minute aggregate of eucryptite and albite. (Am. Jour. Sci., 3d series, vol. 20, p. 257 et seq., 1880.)

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The diallage of these rocks is quite colorless when seen in a thin section, although in the form of powder it is a light grayish green. The prismatic cleavage is well developed, but not as much so as the very perfect parting parallel to the orthopinacoid, which is the characteristic feature of diallage (Pl. VIII, fig. 1). The extinction angle was found to be as great as 35° in the prismatic zone. The plane of the optic axes is perpendicular to the orthopinacoidal parting, and a single axis appears in such sections as show a prismatic angle of nearly 90°. This diallage is very sensitive to the action of pressure and is frequently much bent and twisted. The mineral is sometimes separated along cleavage cracks, the interstices being filled with a colorless, isotropic alteration product, which is probably some variety of chlorite. This substance becomes much more abundant in the more altered forms of this rock and will be again mentioned. The diallage is also often traversed by veins filled with clear quartz.

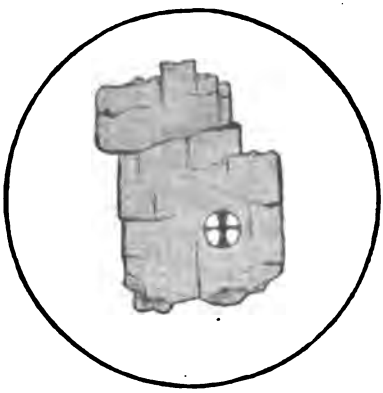

FIG. 6.—Large crystal of zoisite in saussurite of No. 11167. Altered gabbro from Sturgeon Falls. Magnified 350 diameters.

FIG. 7.—Border of both compact and fibrous hornblende around diallage in the Sturgeon Falls gabbro (No. 1167a). Magnified 180 diameters.

The hornblende is an important and constant constituent of the Sturgeon Falls gabbro. It is for the most part compact, and brown in color, having the usual pleochroism. More rarely it is green, or apparently bleached to a lighter shade of brown. In a few instances this latter process has been carried so far as to make it quite colorless. The hornblende is in all cases most intimately associated with the diallage. At times it forms a continuous border of varying width around the diallage crystal, and in other instances it penetrates the latter mineral in irregular areas (see Pl. VIII. fig. 1). In some cases a delicate fringe of minute, colorless hornblende fibers is seen to lie on the outer side of the compact hornblende border and penetrate the saussurite substance (see Fig. 7). This is the same phenomenon that has recently been described by Lossen.[1]

[1] Studien an metamorphischen Eruptiv- und Sedimentgesteine, etc., cf. Jahrbuch preuss. geol. Landesanstalt für, 1884, p. 543, Pl. XXIX, fig. 2. (Cf. Van Hise: Am. Jour. Sci., 3d series, vol. 33, 1887, pp 385 et seq.

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It is impossible to say with certainty what the origin of the compact brown hornblende is. It may be an original product of crystallization in the magma, but its mode of occurrence and its general character indicate that it is probably of secondary origin, having originated by paramorphism of the diallage, as has been shown by myself[1] and by Lossen[2] to be sometimes the case.

No other constituents are important in this rock. Iron in any form seems to be quite rare in it. Occasional cloudy grains, resembling leucoxene, may represent some original ilmenite, while minute crystals of pyrite are still rarer.

The structure of the rock seems to be irregularly granular; none of the components being in any degree idiomorphic. Frequent and abrupt changes in the coarseness of the grain are observable.

All specimens show the action of dynamic forces which have more or less profoundly affected the different constituents. These effects are particularly noticeable in slide No. 11167. Here the rock seems in places to have been crushed and a mosaic of the component minerals to have been formed. Hornblende, generally colorless, is unusually abundant. Colorless chlorite and zoisite are also developed, and all are mixed indiscriminately. In one part of the section a vein is seen to traverse the rock. This is filled with limpid quartz in long, wedge-shaped areas, which extend from one side of the small fissure to the other. This quartz is traversed by long, colorless fibers of the greatest delicacy, and it also contains a good deal of the colorless chlorite, both in solid masses and in those peculiar vermicular groups to which Volger has given the name helminth. These curious groups, which resemble piles of little coins, are sometimes straight, sometimes curved. They are so minute as to be visible only with a high magnifying power. Fig. 8 represents them as they appear when magnified 350 diameters. Exactly the same mineral has been described in the secondary quartz of diabase by Möhl,[3] von Lasaulx,[4] and Schenck;[5] and in that of schalstein and syenite by Hussak.[6]

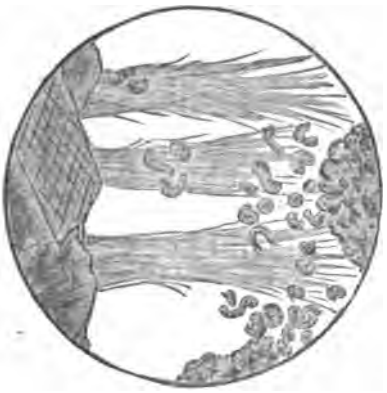

FIG. 8.—Vermicular chlorite (helminth) in quartz. Vein in altered gabbro, Sturgeon Falls.

Saussurite gabbro (*second stage*).—Representatives of this type are found at the lower end of the falls, at *f* on Major Brooks's map, and

[1] Am. Jour. Sci. 3d series, vol. 28, Oct., 1884, p. 262.
[2] cf. Jahrbuch preuss. geol. Landesanstalt für 1883, p. 632.
[3] Neues Jahrbuch für Mineral., 1875, p. 716.
[4] Verh. d. naturh. Vereins d. preuss Rheinl. u. Westf., 1878, p. 216.
[5] Inaugural-Dissertation. Bonn, 1884, p. 22.
[6] Tschermak's mineral. u. petrog. Mittheil., vol. 1, 1878, p. 273.

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at his *e*, at the lower end of the basin below the falls. Nos. 11153 and 11154, from these two localities, are identical in mineral composition with the rocks of the first type above described. They are of a dirty greenish gray color and indications of a schistose structure have already begun to appear in them. Under the microscope they disclose the same constituent minerals as the rocks of the first type; nor are these minerals much more altered, but they show the effects of a profound mechanical action. The feldspar is remarkably fresh and its twinning lamellæ are quite distinct, but it is everywhere crushed, broken, and faulted. The crystals are often plainly seen to be separated into a number of fragments which are removed a considerable distance from one another. Frequently a fine grained mosaic has been formed by the crushing of the larger feldspar crystals. In other cases (especially in section 11154) the feldspar is not so much broken, but it is altered around its edge to an opaque, gray saussuritic mass, while its interior is hardly changed. (See Pl. VIII, fig. 2). The diallage is more altered than in the rocks last described, although it can still be seen to belong to the same species. The crystals are very much bent and twisted and frequently so changed to the light-colored chlorite that only a few minute remnants of the brightly polarizing mineral remain in this nearly isotropic base. (See Pl. VIII, fig. 2.) Fibrous hornblende now becomes more abundant than the compact, and leucoxene patches are seen at intervals.

Nos. 11162, from the upper part of the point *f*, and 11172 from above the falls at *n*, present interesting varieties of this rock. They do not show the effects of crushing to such a degree as do those just described. Indeed the original structure of the rock seems well preserved, although the feldspar is almost completely changed to a fine grained, nearly opaque saussurite, and every trace of the pyroxene (diallage) has disappeared. A pale green, fibrous hornblende occupies the place of this mineral, and there seems to be every reason for regarding it as derived from the diallage; although in No. 11172 the abundant remains of a compact, brown hornblende, evidently in the process of changing to the fibrous modification, suggests the possibility of this mineral having been the original bisilicate constituent. Still there is no warrant for assuming that what is essentially a diallage rockmass was locally developed as a hornblendic rock; and it may be that this is an instance of a remarkable *passage of a pyroxene through a compact into a fibrous hornblende*, for which we shall find much evidence in the studies that follow.

Saussurite gabbro (*third stage*).—As has been already remarked and as may be seen on the map of Sturgeon Falls (Pl. III), there is, between the two points of the more massive rock, *h* and *f*, an area *g*, composed of softer schists. These are easily eroded and have thus occasioned the small bay. The passage from the fresh and massive gabbro at *h* into

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these schists seems to be a gradual one. Along the lower side of *h* there are rocks which are without doubt essentially the same as those above described from this point but which have been profoundly altered by dynamic action, which has also occasioned considerable chemical changes. These rocks, while they show remains of their original minerals, have become decidedly schistose; and by the alteration in their composition, they have developed certain other points of similarity with the schists at *g*, into which they appear gradually to pass. For this reason they have been selected to represent the third and most altered stage of the gabbro in which any sure signs of the original character of the rock still remain; at the same time they possess even more of the characters belonging to the schists, and thus afford just the evidence desired that the latter are the extremely modified form of the massive rock.

No. 11166 is only indistinctly schistose, showing a soft grayish green matrix in which are imbedded altered grains of a reddish feldspar. Under the microscope the original coarsely granular structure of the rock may still be made out. Large but much broken areas of feldspar may be clearly seen where but very little of the unaltered substance remains. For the most part this has been changed to an aggregate of calcite and minute, brightly polarizing needles or plates of a colorless micaceous mineral (probably sericite) along with occasional areas of secondary quartz. What was once the pyroxene or hornblende is now a colorless or extremely pale green, scaly mineral which an examination shows to be chlorite. Between crossed nicols it is isotropic or very feebly polarizing. It was separated by the Thoulet solution from the slightly heavier feldspar and as a powder appears pale green. In a closed tube it gives off water abundantly and becomes dark. With hot sulphuric acid it decomposes and gelatinizes immediately; with hydrochloric acid it decomposes slowly, giving a somewhat yellowish solution, from which ammonium-hydroxide precipitates alumina abundantly. There can therefore be no doubt that this mineral is a chlorite very poor in iron, like the nearly colorless pyroxene from which it is derived. Areas of leucoxene are also common through this rock.

No. 11165, taken from a place only a foot or two below the last and undoubtedly continuous with it, is decidedly more schistose. Under the microscope the minerals are essentially the same as in the last specimen, but the mechanical effects here exhibited are much more intense. The feldspar and the diallage are still recognizable, but the colorless chlorite is much more abundant than in any specimen before described. The feldspar areas have a brownish color, even in the thin section and they are pulled and torn asunder in a remarkable manner. Individuals are often pulled out into more than twice their original length, the separation taking place along a series of interlacing cracks which run approximately perpendicular to the schistose structure

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of the rock. The spaces between the separated fragments are filled with the chloritic mineral. This rock shows every indication of having been enormously stretched and this process, along with attendant chemical changes, has induced its schistose structure. Although it shows under the microscope traces of the original gabbro structure and of the original gabbro minerals, no one would hesitate from a microscopical examination to class it with the schists.

The schists above mentioned as occurring between the two masses of typical gabbro, *h* and *f*, at the Sturgeon Falls, possess an important relationship to these rocks. Taken by themselves, they offer as representative examples of fissile, silky, hydro-mica or sericite schists as could anywhere be found, and yet this narrow band presents such a complete series of transition forms that their origin as derivatives of the massive rock cannot be doubted. In fact, two such series were traced out in detail. One of these was collected on the lower side of *h* and represents the passage of the least altered and most massive gabbro into the typical schist, and the other was obtained near the center of the schist band where a narrow strip of the rock has happily been preserved from the extremest alteration and plainly shows its identity with the gabbro proper. This narrow layer, represented on the map at *g*, is of great value in conclusively proving the origin of the schists in the midst of which it lies and into which it passes on both sides.

No. 11160, from this locality (*g*), was classified in the field-notes with the schists, and regarded as only a harder and more slaty form of these. Indeed, this rock is very schistose, cleaving readily in a direction parallel to the foliation of the more fissile schists. Under the microscope, however, an original gabbro structure is still distinctly seen. Triclinic feldspar, in broken and bent crystals, is plainly visible, while the other constituents have passed into colorless chlorite, quartz and calcite. The feldspar itself is mostly altered into the same compounds, though its form and occasionally its twinning striæ are still preserved.

No. 11161 is a hard, greenish slate, occurring beside the last described rock. Under the microscope, in ordinary light, crystal forms are seen outlined in a dark color, the matrix being colorless. In polarized light, however, these are no longer visible, and there is only a fine grained and schistose aggregate of colorless chlorite, quartz and calcite.

Nos. 11159 and 11158, collected just below the last, are typical schists of a light gray color and somewhat greasy feel. They contain just the same minerals as the rocks last described, but here every trace of original structure has disappeared. There is no indication of the form of any earlier constituents, but those now present are arranged in a finely parallel mosaic of somewhat varying grain. Calcite is much more abundant than in the previous instances. Indeed, in No. 11158 this mineral makes up a large share of the rock.

The other series of transition forms between the gabbro and the

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schists occurs on the lower side of the gabbro mass *h*. This series embraces the specimens of the first, second, and third stages of the gabbro already described from this exposure, and terminates with two specimens of schist, Nos. 11163 and 11164. Any sharp line of demarkation between the typical and massive saussurite-gabbro at *h*, and the fissile, silvery schists, apparently so different, lying below it, was sought long and carefully, but in vain. In fact no such line exists, and if one were to be drawn it must be drawn arbitrarily. The rocks already described from this locality as specimens of the gabbro in the third stage show this. No. 11165 is entered in the field-notes as belonging to the schists, but microscopical examination shows it to be even more closely allied than the almost massive No. 11166, to the gabbro. Traces of the original components and structure are by no means rarest in those rocks which appear macroscopically to have suffered the most profound alteration.

Nos. 11164 and 11163 are light gray, silvery schists, with a somewhat greasy feel; such in fact as might ordinarily be classed as sericite or hydro-mica schists. Their lamination, however, is not in the least regular, but undulatory, and there is a tendency to cleavage not so much along a single plane as in almost any plane parallel to a line. In other words, these rocks have a well marked dip, but hardly any determinable strike. In 11164 especially, there is noticeable a jointing transverse to the strike, and these joint planes often gap open into wide, lenticular seams, as though the rock had been stretched in the direction of its strike.

Under the microscope these rocks are seen to be mostly composed of the nearly colorless chlorite, calcite, and a little secondary quartz. These minerals are interlaced in narrow, wavy bands, producing what may be called after the German idiom, a long "micro-flaser" structure. But even here every trace of the original constituents has not yet disappeared. Occasional battered and broken feldspar remnants are encountered, with their fragments widely separated, and for the most part changed to sericite or calcite. Around these curve and twist the silky chlorite bands developing a sort of "Augen" structure, which may be best seen by examining a section with an ordinary pocket lens. The areas of leucoxene also, before observed, are not lacking here, but these are pulled out in the direction of the schistose structure, until a single one may be followed nearly across an entire section. The bisilicates have evidently all passed into the colorless chlorite, and this mineral on account of its pliability has easily accommodated itself to the circumstances, and has developed the pronounced schistose structure which is now the most important feature of the rock.

These rocks are schists, indeed, of the most characteristic type, but in the light of their field relations and still more from the evidence which a microscopical study of the whole series has afforded, it is evident that they represent the most altered form of the massive gabbro, between two areas of which they are included.

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Chemical analyses.—In order to ascertain what changes have taken place in the chemical composition of the Sturgeon Falls gabbro during the process of its alteration into the schists, the following analyses of specimens illustrating three successive stages of the alteration were made by Mr. R. B. Riggs:

	I.	II.	III.
SiO_2	51.46	38.05	45.70
Al_2O_3	14.35	24.73	16.53
Fe_2O_3	3.90	5.65	4.63
FeO	5.28	6.08	3.89
CaO	9.08	1.25	4.28
MgO	9.54	11.58	9.57
Na_2O	2.92	2.54	.55
K_2O	.24	1.94	3.82
H_2O	3.30	7.53	4.70
CO_2	.20	.93	5.95
Total	100.27	100.28	99.62

Rock powder dried at 105° C.

I. No. 11170, freshest gabbro from the point *h*.
II. No. 11166, gabbro in third stage from the south side of *h*.
III. No. 11164, silvery schist from between *g* and *h*.

At first glance these analyses seem to present a curious anomaly. The intermediate rock, No. 11166, appears to differ more from the original type than the most altered specimen, No. 11164. A closer examination, however, shows that the nature of the chemical processes which have gone on in the two cases is essentially different. In the first case, No. 11166, this has been chiefly chloritization, while in the second case, No. 11164, the chloritization has been less, but sericitization and carbonatization have also been extensive.

The abundance of the colorless chlorite, above described as present in No. 11166, here manifests itself in the very low percentage of silica and in the correspondingly high percentage of alumina, together with the increase of both magnesia and water. The iron is unusually low in this chlorite because it did not exist in the mother rock; still there has been a gain rather than a loss of this ingredient. The lime has here been to a great extent removed, presumably in the form of the soluble bicarbonate, while the slight sericitization, above mentioned in the description of this rock, is indicated by the increase of the potash.

In the analysis of No. 11164, the less extent of the chloritization is shown by the less, although proportionate, increase of alumina and water and decrease of silica, while the iron and magnesia remain about the same as in the mother rock. Here the lime has been partly removed as before and partly retained as calcite, visible everywhere through the rock and indicated in the analysis by the 5.95 per cent of CO_2. The sericitization, so apparent under the microscope, is here shown by the great increase in potash and the exchange of the soda for potash.

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LOWER OR LITTLE QUINNESEC FALLS.

The rock exposure of Lower Quinnesec Falls is not confined to the immediate vicinity of the falls but it extends, especially on the left bank of the river, for a considerable distance below. This portion forms a high, abrupt and homogeneous ridge, of uniform composition and structure, the description of which may be advantageously separated from that of the rocks occurring immediately at the falls.

We shall, therefore, consider under two successive heads:

(1) The greenstones of the so-called "*Gabbro Ridge*" of Major Brooks.

(2) The greenstones of the Lower Quinnesec Falls.

Greenstones of the so-called "Gabbro Ridge" of Major Brooks.—For a mile below Lower Quinnesec Falls, the north bank of the river is skirted by an almost perpendicular wall of massive greenstone. This wall is sometimes over a hundred feet in height, and has every appearance of being a great dike. Although for the most part it is quite massive, it presents frequent and very instructive evidence of the effect of great pressure upon it. It is seamed and gashed, broken and torn, and contains schistose bands of varying width. Since the continuity of these bands with the massive rock is established, their study is calculated to throw light on the subject of dynamical metamorphism.

Major Brooks designated the rock which composes this ridge as a "massive gabbro," and correllated it with the above-described saussurite-gabbro of Sturgeon Falls. My studies have, however, failed to disclose in this rock any trace of pyroxene. In addition to its feldspathic constituent, which is generally altered to saussurite, it contains in abundance that peculiar pale green and more or less fibrous variety of hornblende which is quite universally conceded to be of secondary origin. What the primary form of all this green hornblende was, it is now impossible to ascertain with certainty. It is of a kind well known to originate from the alteration of pyroxene. The rock as a whole also bears decidedly the character of a diabase or pyroxene rock; and yet, not a trace of pyroxene has been discovered in any of the Menominee River greenstones, if we except the light colored diallage of the Sturgeon Falls gabbro. Whenever the pale green hornblende can be traced back to an original form, it is seen to be derived from a compact brown or basaltic hornblende. This fact was substantiated not merely for the rock composing the ridge here under discussion, but it is also true for the several other localities examined on the river.

This brown hornblende is seen first to turn green by a reduction of its iron to the ferrous state, or to become bleached by loss of its iron, and finally to break up into an aggregate of fine hornblende needles exactly similar to that commonly formed by the alteration of pyroxene to uralite.

It is, of course, impossible to prove that some of the secondary fibrous hornblende has not been derived from pyroxene. Indeed, it seems very probable that both augite and compact, brown hornblende may have

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existed side by side as original constituents of the rock, and that both finally succumbed to the same process of alteration, although the hornblende resisted this much longer than the augite. Such, in point of fact, has elsewhere been observed to be the case where both minerals have undergone uralitization in the same rock;[1] and this would account for the frequent survival of brown hornblende cores where every trace of pyroxene had disappeared.

If this is not the true explanation of the genesis of these rocks, there are but two other hypotheses possible—either that the original rock contained no pyroxene, but was a diorite, composed of plagioclase and brown hornblende; or, that the pyroxene has passed into uralite through an intermediate compact, brown hornblende. Opposed to the first of these suppositions is the structure of the rock, which is diabasic rather than dioritic. On the other hand, considerable evidence afforded by various of the Menominee rocks, as well as observations made elsewhere by the writer[2] and by Lossen,[3] indicate that the latter hypothesis may possibly be true. Inasmuch, however, as the rocks here under discussion afford no trace of pyroxene, it hardly seems justifiable to call them anything but diorite. We shall encounter still more distinct examples of this type farther up the river.

All the specimens collected from this greenstone ridge show an advanced stage of alteration. Some obtained from the western extremity of the ridge, near the Michigan bank of Lower Quinnesec Falls, have a coarsely porphyritic structure, and are among the freshest specimens that were procured. This variety of the rock is represented by Nos. 11034, 11035, and 11098. Of these the last is perhaps the most typical. To the unaided eye it shows a light greenish gray matrix, thickly studded with irregularly shaped crystals of opaque white feldspar (saussurite) from one-half centimeter to two centimeters in diameter. A closer examination reveals many brightly reflecting cleavage surfaces of another and darker mineral. These are of about the same size as the feldspar crystals, but their continuity is interrupted by small opaque spots, which produce the mottled structure recently termed by the writer *pœcilitic*.[4] The color of these cleavage surfaces, which with the aid of the microscope are found to belong to large individuals of a somewhat altered hornblende, is so nearly like that of the groundmass of the rock that unless their reflection is caught in just the right light they escape detection.

The large porphyritic crystals of feldspar are almost wholly changed to saussurite. This has a dull gray color, and is nearly opaque even in the thinnest sections. A high magnifying power resolves it into an aggregate of minute zoisite needles. Curiously enough, these feldspar crystals show a clear zone of unaltered substance around their outer edge.

[1] Bull. U. S. Geol. Survey, No. 28, p. 45.
[2] Am. Jour. Sci., 3d series, vol. 28, p. 262, Oct., 1884.
[3] Jahrbuch preuss. geol. Landesanstalt für 1883, p. 632, Berlin, 1885.
[4] From ποικιλος, mottled. See Am. Jour. Sci., 3d series 1886, vol. 31, p. 30.

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This fresh and finely striated portion presents a striking contrast to the dull gray saussurite, and it is difficult to imagine how it has so completely escaped the alteration which has attacked the rest of the crystal, unless it is the product of a more recent growth.

With the exception of groups of ilmenite grains, which are beautifully fringed with a leucoxene border, the remainder of this rock is composed almost wholly of hornblende. In its freshest state this mineral has a compact structure and coffee brown color, with the usual pleochroism and other optical properties of the species. Its first phase of alteration consists in turning green, and this is followed by a gradual bleaching. This process continues until the mineral has become quite colorless, without, however, losing its compact structure. In the larger individuals of compact hornblende, whether this is brown, green, or colorless, occur numerous small lath-shaped feldspars, which produce the mottled or "pœcilitic" structure above alluded to. These seem to be less completely changed to saussurite than the larger feldspar crystals, but they often contain the zoisite crystals in a more perfect state of development.

It has already been mentioned that these hornblende crystals show an advanced stage of alteration. The hornblende itself is bleached until it is nearly colorless. The final change seems to be the breaking up of this bleached hornblende into an aggregate of colorless needles, resembling tremolite. In other cases, however, it is changed in irregular patches to a colorless chlorite which is quite isotropic, and only visible between crossed nicol prisms. The peculiar manner in which this takes place deserves particular notice, and is represented in Fig. 9. The hornblende substance remains in interlacing veins between the chlorite areas. It is brightly polarizing and may be often seen, as in the figure, to be continuous with an unchanged hornblende individual. This peculiar mode of alteration is doubtless also conducive of the "pœcilitic" effect above mentioned. The clearness, transparency, refraction, etc., of both hornblende and chlorite are so nearly identical that this structure is wholly invisible in ordinary light, and the effect of polarized light in transforming the apparently homogeneous and colorless mass into its two strongly contrasted elements is very striking.

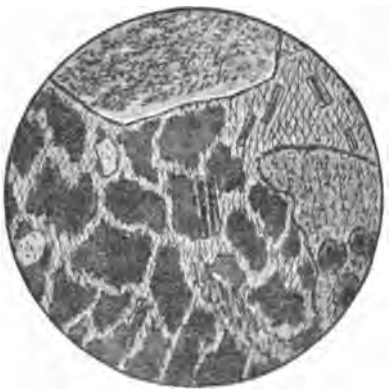

FIG. 9.—Hornblende undergoing alteration to colorless chlorite in a porphyritic diorite from Lower Quinnesec Falls. Nicols crossed. Magnified 80 diameters.

No. 11034 is essentially the same as the specimen just described, except perhaps that it is more altered, and hence contains less of the original compact brown hornblende. Most of the hornblende, indeed,

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in this rock is colorless, and much of it is fibrous. That which still retains any color is for the most part green.

No. 11035 was not sectioned, but in the hand-specimen it exactly resembles the others.

No. 11032, collected with the specimens last described, is a beautiful, fresh looking rock, without porphyritic structure, but with its hornblende in long, slender, greenish-black crystals. Under the microscope the feldspar of this rock is seen to be less altered than in those above described. Saussurite is abundantly developed in it, but not so extensively as in the porphyritic crystals of the other specimens. There is, however, here no brown hornblende. This mineral is all of a pale green color, or it is changed to chlorite, which sometimes contains sharp crystals of epidote. Ilmenite is abundant and is fringed with leucoxene.

The above described specimens, from the extreme western edge of the ridge near the falls, although they are the least altered form of the rock, hardly represent its most typical aspect, as the ridge is followed along the river bank, westward from Sandy Portage, its high and almost perpendicular front is found to be composed of a light green or grayish-green, fine grained or aphanitic rock. This is compact and massive in structure, but everywhere profoundly seamed and jointed. It is cut by cross-gashes and parted joints, and gives every indication of having been pulled or crushed—at all events, of having been subjected to enormous mechanical strains. The joints and seams often run in many different directions, producing a regular breccia without cement. The rock is also much slickensided, frequently so much so as to produce a schistose structure. The layers thus formed sometimes bend around more massive cores, which seem to have resisted the rubbing action.

The formation of what are above described as "cross-gashes" is very curious. At times the entire face of the rock wall is scarred with approximately parallel gaping seams, closely resembling the rents formed in moderately dry clay or putty when this is stretched. A single opening does not extend for any great distance, but a great number of them of all dimensions, closely crowded together, may produce an irregular sort of foliation. The general appearance of a rock thus gashed is represented in Fig. 10, which was drawn from a hand-specimen. This of course can give only an approximate idea of the appearance of this structure in a large rock-mass. These gashes seem to have been produced by a stretching of the rock, or, what amounts to the same thing, by a bulging perpendicular to the action of some great pressure. They resemble the "*klaffende Risse*," described by Heim in the Alps, and already mentioned in Chapter I (p. 43). The edges of the seams are ragged as though they had been formed by a forcible tearing asunder of the rock after it was solid. They are often filled with subsequent infiltrations of secondary minerals, like calcite or quartz, but more frequently they are open.

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No. 11028 is a fair average specimen of the rock composing this ridge. It is a grayish green, compact, homogeneous mass, which is but little jointed. Under the microscope it is seen to be mainly composed of a

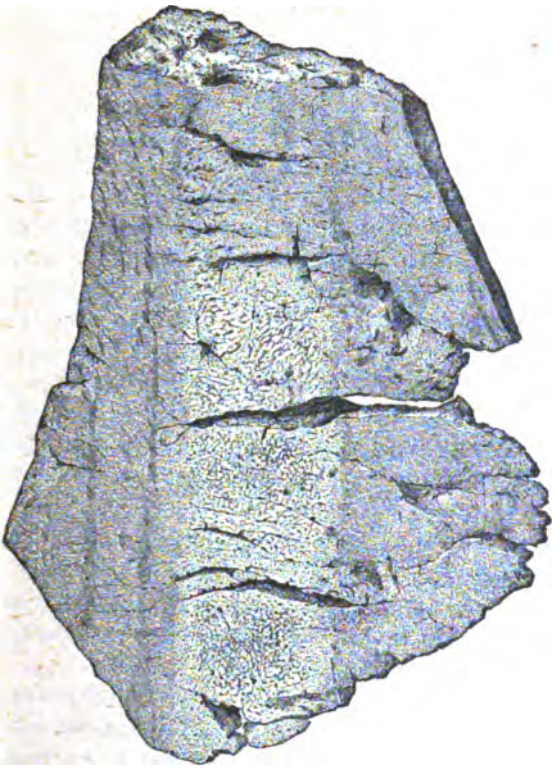

FIG. 10.—"Cross-gashes" in a greenstone from Lower Quinnesec Falls.

finely fibrous, pale green hornblende of secondary origin, of saussurite, quartz, and ilmenite. The structure of the rock has been almost entirely destroyed in the course of the mineralogical changes which have taken place in it. As the new minerals have formed they have wandered from the position occupied by the older ones and have thus produced a fine grained and confused aggregate in which remains of larger rectangular feldspars or hornblende crystals are only rarely discernible. The ilmenite is scattered about in minute dots, each surrounded by its own leucoxene border. The quartz is in irregular patches and bears every evidence of being secondary in its origin.

No. 11033, from near the western end of the ridge, is almost identical with the specimen last described, but contains more quartz, and the remains of the feldspar imbedded in a dark gray, opaque matrix.

No. 11031 is a specimen collected from very near the spot where No. 11028 was obtained, and the two, when taken in connection, show in a very clear and beautiful manner the effect of mechanical action in modifying both the macro-structure and the micro-structure of a solid rock.

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In spite of great present differences, there can be no doubt that the two specimens were once portions of a continuous mass. They were taken side by side from a single ledge which showed nothing like a line of contact between two different rocks. One is a typical massive greenstone, with hardly a joint-plane visible in it; the other, while agreeing closely with the first in color and texture, is deeply cracked, gashed and seamed, and possesses a pronounced schistose structure. The original form of both specimens was doubtless an igneous rock of the diabase type, which has been subjected in one case (No. 11028) to chemical (metasomatic) and in the other (No. 11031) to dynamic metamorphism.

Rocks may be altered by simple pressure, but the accumulated strains which are generated within them are relieved and adjusted by overcoming the force of cohesion along certain planes. Here there will be a shearing motion of greater or less extent, and a consequent crushing of the rock. The rent is soon healed by the crystallization of new compounds which cement the crushed fragments, and in this way a schistose band, of width varying with the intensity of the force, may be developed in the midst of an otherwise solid and massive rock; or a number of such bands may be formed parallel to one another, and together imparting to the rock the appearance of a foliated or even a banded schist.

Conclusive proof of this process might be difficult to discover without the aid of the microscope, but this instrument is happily able to afford sufficient evidence to overcome all doubt. We shall have many instances of such action to describe in the sequel, each of which will exemplify some particular phase of the process.

The two rocks here under discussion, however, illustrate this general principle in an admirable manner. Plate IX represents the appearance of each of them in a thin section as seen under the microscope. The structure of the first, No. 11028, is, as above described, a granular aggregate of fibrous hornblende, chlorite saussuritized feldspar, quartz, and ilmenite, produced by chemical action alone in recrystallizing the elements of the original constituents in new compounds more in accordance with the altered physical conditions to which the rock was subjected. The component minerals of the second rock (No. 11031) are not so different from the last, but the story of its origin is told in its structure. The primary constituents seem to have been literally pulverized by crushing. The feldspar crystals have been pulled apart, the fragments being separated a considerable distance (always, however, in the same direction), but it is still possible to recognize fragments which once belonged together. The substance of this feldspar is remarkably fresh, another instance of the chemical action which takes place in this mineral being inversely proportional to the mechanical action which has affected it. The separation of the feldspar fragments is due to a stretching action and the spaces between them are filled with a pale green and almost isotropic chlorite. This mineral has

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evidently been developed at the expense of the hornblende, which is here only rarely to be found, and then always in bands where the mechanical deformation has been less intense. Where it is found, however, this hornblende is identical with that occurring in No. 11028. The ilmenite and leucoxene are seen as before, but the former is far less abundant while the latter is proportionately more abundant. When the ilmenite has completely disappeared, the leucoxene forms bands and stringers, thus aiding in the production of a schistose structure.

This development of chlorite out of the hornblende substance seems to be a very important feature in the stretched basic eruptive rocks and many other instructive examples of it will be given beyond. It has a definite bearing upon the origin of the fine grained chlorite schists which accompany and are interstratified with so many of them.

Nos. 11041 and 11042 form an instructive pair of specimens, collected near the river bank toward the western end of the ridge. At this particular locality there is a well marked band of green schist traversing the here generally massive greenstone in a direction S. 70° E. The schistose structure is irregular and undulatory, and on either side there is a gradual passage from the schist into the massive rock. No. 11042 is from the surrounding mass immediately at the edge of the schist band. In a hand-specimen it appears to be considerably altered, of a gray color, and without any cleavage. Under the microscope the original structure is easily recognizable. The rock is largely composed of stout rectangular feldspars, with a somewhat rounded outline, and internally changed to saussurite, though their periphery is mostly clear. Between these are the remains of former hornblende (possibly pyroxene) individuals now represented only by amphibole fibers and chlorite. Beautiful skeleton forms of leucoxene, composed of three sets of parallel bands, reproducing the rhombohedral parting of the original ilmenite, are abundant.

No. 11041 is the same rock as the last in a much more altered form. The feldspar is mostly changed to calcite, and the hornblende to chlorite. The structure has wholly disappeared and there is a very fine mosaic of quartz and secondary albite substance. Still, the same skeleton forms of leucoxene remain and there is no doubt that the two specimens represent the same rock in different stages of alteration, the more changed form having become decidedly schistose.

Farther west, in the immediate vicinity of Lower Quinnesec Falls, the abrupt face of the diorite ridge proper retires a short distance from the river bank. Along the shore the massive greenstones give place to slaty rocks, which cleave into rhomboidal prisms. They have no proper strike, but seem to break with equal readiness in all planes parallel to a line; and this line is here nearly perpendicular to the surface. No. 11043 is one of these rocks of a greenish color. Under the microscope it is seen to have been so profoundly altered that it is now impossible to assert from internal evidence what its original character was. Still, its geo-

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logical position indicates that it was once a part of the gabbro or diorite ridge, and there is nothing in its present structure that directly contradicts this supposition. The rock has a pronounced, although irregular and undulatory, schistose structure. It consists largely of a fine grained matrix, composed of chlorite scales, arranged parallel to the direction of schistosity. With this mineral are associated quartz, feldspar, opaque black grains, probably magnetite, and occasionally sharply defined crystals of muscovite. Imbedded in this groundmass are larger feldspars, sometimes in well developed crystals, sometimes in fragments. The substance of these is but very little altered, and yet their outline is made indistinct by the penetration into them of the chlorite scales. They often appear to have been much squeezed and broken, the fragments being more or less separated. Grains of quartz are occasionally seen, which have also been fractured by pressure. Calcite, due to alteration, is also sparingly present.

Similar rocks, more or less schistose and varying from a dark green to a light gray, occur from this point along the river bank all the way to the falls.

No. 11046 is from the light silvery-gray, greasy-feeling band, which projects into the basin at the foot of the falls. This is a typical sericite schist. Under the microscope it is seen to have a finely schistose structure, produced by the parallel arrangement (often in bands) of quartz grains, sericite scales, and chlorite, which is nearly colorless. Along with this is a large amount of calcite, also distributed in bands. There is no feldspar visible. The most interesting constituent is rutile. This mineral is sparingly distributed through the whole rock in very minute and sharply defined crystals. These have a pale yellow color, a high index of refraction, and the usual twinned forms. In certain portions of the section there are dull gray, opaque spots, which are yellow in reflected light. These are not continuous, but are more or less broken up and pulled out in the direction of the schistose structure. They contain occasional dark red and irregularly shaped grains of rutile, but for the most part they are composed of innumerable small rutile needles (quite like the "*Thonschiefernadeln*" of the Germans) so closely crowded together as to form an opaque mass, only resolvable with a high power of the microscope. From these dense masses the other little needles in the other parts of the rock seem to have wandered.

This rock is almost identical with certain light colored, very fissile schists occurring on the opposite side of the river (cf. No. 11011, described beyond), and the strike of these two exposures seems to identify them as belonging to a single band.

Greenstones of the Lower Quinnesec Falls.—Passing now to the rocks exposed along the northern or northwestern shore of the basin below Lower Quinnesec Falls, we find alternating bands of lighter and darker colored greenstones, each accompanied by schistose layers, which present instructive examples of dynamic metamorphism.

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The accompanying map (Pl. IV) represents an enlarged portion of Major Brooks's map of Lower Quinnesec Falls. Commencing at the western corner of the basin there are, along its northern shore, three bands of dark and two of light colored rocks. The two kinds of structure, massive and schistose, are so intimately connected in both of them that it is impossible to escape the conviction that the latter has been secondarily developed.

If we begin at the extreme western end of this exposure, at the corner of the basin where a sharp bend in the river's course has produced a low, sandy beach, we discover that the rocks are of a dark green color. The first specimen taken from this band (No. 11001) is massive and jointed. No feldspar is visible, except in large porphyritic crystals, which are not common. Even in this massive rock occasional narrow bands, having a wavy foliation, may be seen. These resemble slickensides, and represent planes of slipping or sliding in the massive rock (No. 11002). Tracing these rocks a short distance to the east, the wavy schistose bands become more and more numerous, until the whole mass becomes decidedly slaty, and has a greasy feel. This foliated rock strikes slightly south of east and dips steeply toward the north. The laminæ are frequently separated and bulged into lenses, which are either filled with quartz or are still open and then coated with drusy quartz (No. 11003). These slaty rocks have a dark gray color, and, in some respects, resemble hydro-mica schists, but yet it is impossible to separate them in the field from the dark green massive rocks above described, *as each passes by insensible gradations into the other.*

Under the microscope, No. 11001 appears as a medium grained aggregate of feldspar and pale, fibrous hornblende with some ilmenite and leucoxene. The structure is still well preserved. The feldspar is in stout, columnar crystals, all distinctly striated and often considerably changed to zoisite or epidote. The hornblende is in irregular, ragged masses or in minute needles. The pale, fibrous sort is plainly seen to have been derived from a compact, darker green and pleochroic variety; but farther back than this (i. e., to a possible original pyroxene) it can not be traced. There is also a little pale green chlorite, looking much like the secondary hornblende, except between crossed nicols, where it is nearly isotropic.

No. 11002, taken from one of the narrow schistose bands, has plainly been produced by a shearing or sliding within the last described massive rock, and presents an interesting relationship to it when placed under the microscope. The two are plainly identical as far as the component minerals are concerned, but the structure of the latter has undergone a great change. The grain at first glance appears to be finer, but this is soon seen to be due to a crushing of the original minerals. The feldspars especially are very much broken and their parts more or less separated. This mechanical action has been attended by increased chemical activity. The original substance of the crushed feldspar crys-

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tals is hardly as much changed as in the preceding instance, but there has been a considerable recrystallization of new feldspar substance (probably albite). The hornblende, because of its secondary nature, is more like that in the massive rock (No. 11001), but even this is sometimes sundered and torn. Chlorite is much more abundant, especially in the interstices between the fragments of the broken feldspar crystals. It is sometimes filled with very delicate and minute, though extremely sharp, epidote crystals. The ilmenite is more extensively changed to leucoxene than before, and, in some cases, shows a decided pulling out in the direction of the schistose structure. On the whole, many of those metasomatic changes which the greenstones most commonly show are here seen to have been accelerated and intensified by the mechanical force which has crushed the rock and so changed its structure. Thus the two forces—dynamical and chemical—may go hand in hand and together produce a rock which is both structurally and mineralogically very different from that out of which it has been derived.

Passing eastward along this exposure, we next come to a wide band of much lighter colored rock, which extends as far as the lower side of the small cove, situated on the right bank immediately below the falls. This band exhibits, in a most admirable manner, the secondary development of schistose layers in a massive rock, and is well deserving of careful study. The most typical and least altered form occurs just at and below the corner of the small cove. This is a medium grained, massive aggregate of opaque white saussurite and light green, fibrous hornblende, and it closely resembles, in its external aspect, the barrier rock at both Upper Quinnesec and Sturgeon Falls. Nos. 11008 and 11009 represent this occurrence, but even the most massive specimens which could be obtained are seamed with cracks approximately parallel in direction and coated with a lamellar, soft green mineral like that in the adjoining schists. This is shown by examination to be chlorite. On both sides of the massive portion of this band the parallel cracks become more and more abundant (No. 11004 below, and No. 11010 above), and on the lower side of the small cove the rock passes, without any break in its continuity, into silky schists (No. 11011), like those above described from the opposite side of the river (cf. No. 11046, p. 84).

Under the microscope, the least altered specimens of this rock (Nos. 11008 and 11009) are found to bear a close resemblance to the light colored gabbro of Sturgeon Falls (see p. 68), except that in the present instance no trace of diallage is discernible. The structure of the two rocks is the same. The feldspar is here also replaced by the same gray, opaque saussurite, in which, with a high power, zoisite and calcite may be easily detected. The hornblende, as seen in a microscopic section, is practically colorless. Only occasionally are traces of a greenish tinge observable. Between crossed nicols this mineral generally exhibits a homogeneous extinction, so that it can not be regarded as truly fibrous, and yet there can be no doubt as to its secondary nature. Its edges are

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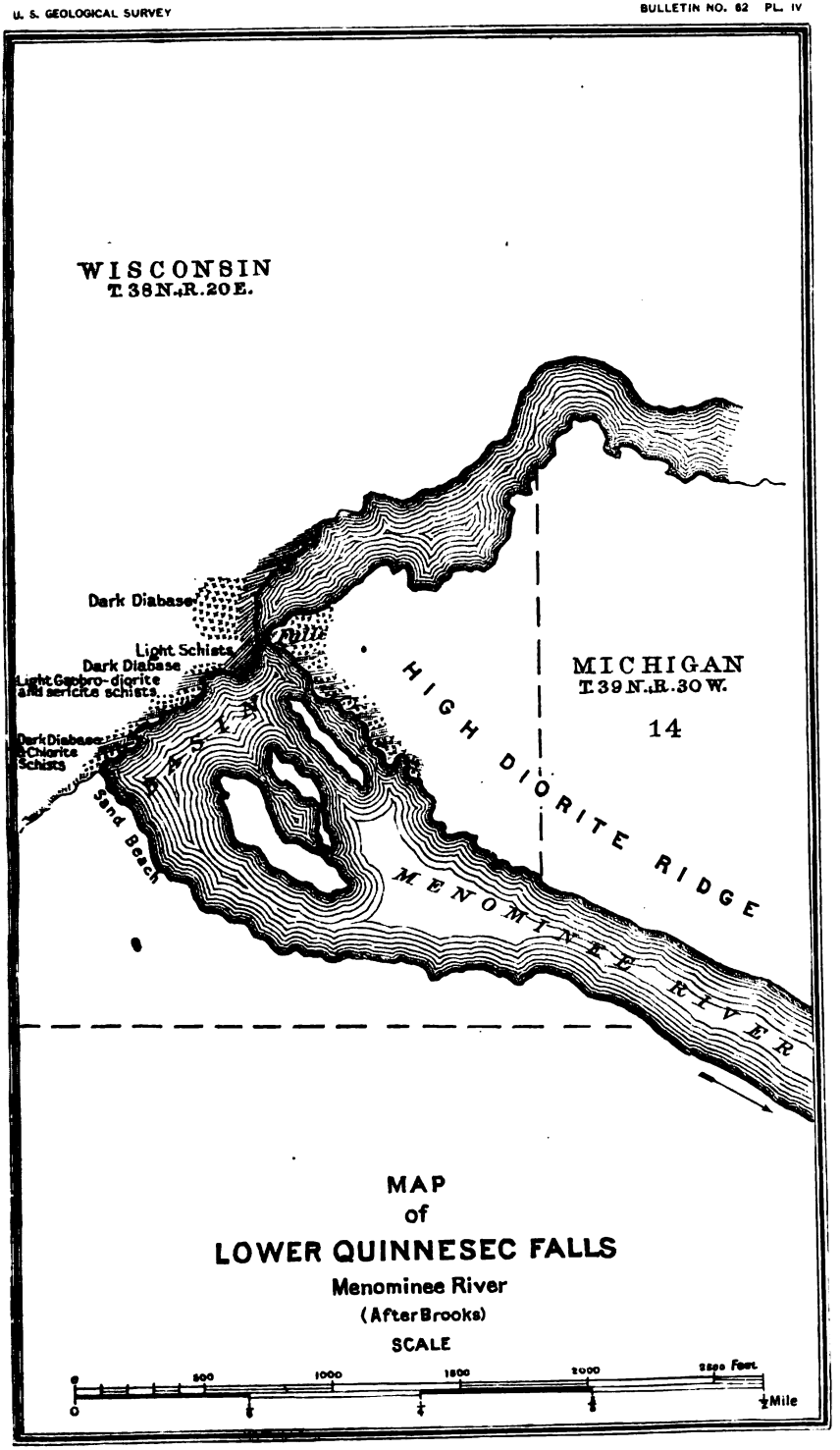

MAP
of
LOWER QUINNESEC FALLS
Menominee River
(After Brooks)
SCALE

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ragged and there is a decided tendency to separation into fibers, even when these are not actually present. It is noteworthy that this secondary hornblende can only be traced back (and that in rare instances) into a more compact greenish or brownish variety of the same mineral. In none of the thin sections is there any positive evidence that diallage was ever present; and yet the close similarity of this rock to the Sturgeon Falls gabbro naturally suggests it. If the diallage were originally present it has completely changed to the pale hornblende, while the brown hornblende longer resisted the bleaching action, and hence sometimes still remains. If this were not the case, we are compelled to assume one of the two other alternatives suggested in the case of the porphyritic diorite from the other side of the river, No. 11098 (see p. 78).

The pale hornblende is often partially altered to colorless chlorite, and the ilmenite is more or less changed to leucoxene.

Nos. 11004 and 11010, taken from either side of the above described band, represent somewhat schistose varieties of it which have been produced by the action of pressure. That this is actually the case is admirably shown by a microscopic examination. The hornblende of the original rock seems to have passed completely into a very pale or colorless chlorite. Saussurite, on the other hand, is less abundantly developed than in the more massive rock above described, and it is disposed in narrow veins or in small, irregular spots. The ilmenite has given its place to a dark gray substance resembling leucoxene. This is drawn out in stringers following the direction of the schistosity, and in the center of these a yellow grain of rutile may sometimes be observed. Calcite is also present. The structure of the rock is completely different from that from which it is supposed to have been derived. It is now composed largely of a fine grained groundmass. This is made up of a microgranitic aggregate of minute grains of an unstriated substance resembling quartz, but which, from its high specific gravity, is probably a feldspar. These grains, together with chlorite scales, leucoxene, some calcite, and an occasional bit of epidote or sericite, are arranged so as to produce an indistinct schistose structure, the bands of which bend and wind around larger porphyritic individuals of feldspar. In this way a lenticular or "Flaser" structure results, which, however, is hardly discernible, except under the microscope. A very particular interest attaches to the porphyritic feldspar crystals of these rocks. In comparison with those in the more massive rock (11008 and 11009), they are but slightly altered to saussurite; indeed, for the most part, they are surprisingly fresh and glassy. Glistening cleavage surfaces may be readily detected with the unaided eye, and under the microscope this feldspar appears in clear, colorless grains, almost wholly free from inclusions of any kind. Occasionally these possess a light brownish tinge, due to some evenly distributed pigment. Between crossed nicols this clear feldspar substance presents sharp twinning lamellæ and a comparatively high extinction angle.

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The individual crystals are invariably broken and the fragments are more or less separated. The intervening spaces are filled with a micro-granitic groundmass, as shown in Plate VIII, figs. 1 and 2, of other similar, though more acid rocks from Upper Quinnesec Falls and from the vicinity of Marquette, Michigan.

The clearness and freshness of this feldspar would at first suggest the probability of its being a secondary crystallization, as, for instance, albite is often found to be. This, however, is shown not to be the fact, first, by the broken state of all the crystals, indicating that they must have been in existence when the rock was pressed and crushed; and, second, by their physical properties which show that the feldspar is labradorite. Upon isolation this feldspar was found to have a specific gravity of 2.69; and in cleavage pieces parallel the basal plane, it gives an extinction angle of 12° to 20° on each side of the twinning-trace.

The survival of the original feldspar in an almost unaltered state, in a rock so profoundly changed by mechanical action, naturally occasioned some surprise. Examples of the same sort have already been cited (e. g. Nos. 11154 and 11165 from Sturgeon Falls, and No. 11032 from the diorite ridge below Lower Quinnesec Falls), and so many cases of a like character were encountered from other localities that the occurrence of the freshest feldspar in the most crushed rock must be regarded as the rule.

I know of no way of interpreting this phenomenon, substantiated by so many instances, except by supposing that the pressure, which acts powerfully in stimulating chemical action in the solid rock, is relieved on the harder grains of a crushed band, since these are able to change their position by slipping among the softer materials.

The nearly vertical, silvery schists (No. 11011) which occupy the western corner of the little cove just below the Lower Quinnesec Falls, represent only a more highly metamorphosed state of the rocks above desrcibed. They are extremely soft, fissile, and schistose in a hand-specimen. Under the microscope they closely resemble the groundmass of the last described rocks (Nos. 11004 and 11010). The granular aggregate is so disposed as to produce a decided schistose structure. Both calcite and sericite have become more abundant, while the porphyritic feldspar crystals have completely disappeared. The leucoxene also can no longer be found, but the long lines of very sharp and minute rutile crystals, which are not present in any of the more massive related rocks, appear to have taken its place.

The perfect continuity of the massive rock (Nos. 11008 and 11009) with these schists, through the intermediate member (11010) is admirably shown in the exposure at the western end of this small cove.

The following chemical analyses of these three specimens have been made by Mr. R. B. Riggs.

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I. No. 11008, Gabbro-diorite from Lower Quinnesec basin.
II. No. 11010, Schistose form of the same rock.
III. No. 11011, Seriate schist adjacent to last.

	(I.)	(II.)	(III.)
SiO_2	47.96	49.19	46.21
Al_2O_3	16.85	18.71	18.38
Fe_2O_3	4.33	5.03	3.30
FeO	4.17	4.04	3.90
CaO	13.25	5.92	6.28
MgO	9.15	7.98	7.03
Na_2O	1.25	1.44	2.14
K_2O	.30	.77	.35
H_2O	2.89	5.05	3.82
CO_2	.08	1.82	8.32
Total	100.23	99.95	99.73

TiO_2 not determined.

The close agreement between these analyses is striking. The low percentage of iron sufficiently accounts for their uniformly light color. The most striking difference is perhaps the loss of calcium and the lesser loss of magnesium, both of which were undoubtedly carried off in the form of soluble carbonates when the rock was crushed. The water is contained in the pale chlorite, which first increases in amount and then decreases, as its components are transformed into carbonates. The sodium was first contained in the feldspar and the steady increase in its relative amount is probably due to the development of the sericite-like mica, which may be a paragonite.

It is interesting to compare the first of these analyses with that of the Sturgeon Falls gabbro (I on p. 76), the close resemblance of which to the rocks here under consideration has already been alluded to. The only noticeable difference is a slightly larger proportion of silica and a smaller proportion of alumina and lime in the Sturgeon Falls rock.

Passing now still farther to the eastward, we come to the second band of dark-colored greenstones (see map, Pl. IV). These follow directly after the narrow exposure of the above-mentioned silvery schists in the western corner of the little cove and form a great part of its northern shore. They resemble the rocks occurring in the band first described, and present both massive and schistose varieties, which grade insensibly into each other in a manner not less instructive than that in the two bands already considered.

Nos. 11012, 11013, and 11021 (the first two from massive portions of this band along the shore of the small cove; and the last from the Wisconsin side of the river directly opposite the falls) are essentially identical in appearance and composition. In the hand-specimen they form a compact, aphanitic mass, of a dark green color. Under the microscope the originally diabasic nature of the rock is at once apparent, although

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the extensive mineralogical changes which have gone on have greatly obscured its former structure. The components now present are almost wholly secondary. These are hornblende, chlorite containing epidote, quartz, and leucoxene. Ilmenite and occasional traces of feldspar are the only original constituents which remain. Still the disposition of the secondary minerals is such as to outline a diabasic or ophitic structure often with great distinctness. The feldspar is rarely well preserved; but a narrow zone of the unaltered substance of this mineral often outlines a stoutly lath-shaped crystal, even when its interior is wholly changed to an aggregate of quartz, chlorite, and epidote. The hornblende has a curious appearance. Its crystals are brownish and nonpleochroic with a somewhat granulated surface, so that it externally resembles diallage. Its cleavage and optical properties prove it to be undoubtedly hornblende, although this superficial likeness to diallage is so strong as to almost compel the conviction that it has originated by paramorphism from a pyroxene. This brown hornblende is seen with a high power to be gradually changing to a green variety, in which a pleochroism for the first time becomes apparent. This also frequently passes over into a fibrous hornblende. The chlorite epidote aggregate in these rocks is very finely developed. The chlorite is of an emerald green color and distinctly pleochroic. It appears between crossed nicols as isotropic or polarizes with a maroon tint. The epidote is in sharp, light yellow crystals, with the characteristic shape and optical properties of this species. The microscopic appearance of this aggregate is represented in Pl. XI, fig. 1, drawn from a specimen collected below the Upper Quinnesec Falls (No. 11049). The literature relating to it has already been cited (Chapter I, p. 57). The epidote crystals have been described from the Menominee region by Wichmann[1] and others as secondary augite. This chlorite epidote aggregate covers considerable areas and occupies the place of both the feldspathic and the pyroxenic constituents. In addition to the minerals already named, ilmenite, with its leucoxene border, pyrite and secondary quartz are quite abundant in these rocks.

No. 11014, taken from a narrow, schistose band in the massive greenstone (No. 11013), shows in a remarkably clear manner how the dynamic metamorphism of this rock has been accomplished. In this instance there can not be the least doubt as to the continuity of the rock-mass. The hand-specimen No. 11014 has a decidedly schistose structure, and under the microscope it shows the effects of mechanical crushing and attendant mineralogical changes with great distinctness. The whole rock, with the exception of certain remains of the larger feldspar crystals, has been reduced to a fine grained mass, showing an aggregate polarization. Light green chlorite has been largely developed and has completely replaced all the bisilicate elements. The parallel arrangement of the scales of this mineral is what produces the schistose

[1] Geol. Wisconsin, vol. 3, 1876, pp. 623, 624.

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structure, and it surrounds and incloses the small grains in the manner which has already been explained in connection with No. 11031 (p. 81) and illustrated in Pl. IX, fig. 2. The clear, secondary grains forming this mosaic are certainly, to some extent at least, quartz, while a portion of them may be an unstriated feldspar. Calcite has been largely developed in the schistose rock, and the leucoxene is replaced by rutile, either in stout, yellow grains, or in minute, sharp crystals arranged in long, sinuous lines.

The mechanical action which produced this schistose band has therefore resulted in the crushing of the rock, and the almost total disappearance of all of the original components. The comparatively slight change in the chemical composition of the rock as a whole may be seen from the two following analyses of Nos. 11021 and 11014, made by Mr. R. B. Riggs.

I. No. 11021. Dark massive greenstone, Lower Quinnesec Falls.
II. No. 11014. Dark schistose greenstone, forming a band in the last.

	(I.)	(II.)
SiO_2	43.80	44.49
Al_2O_3	16.08	16.37
Fe_2O_3	9.47	5.07
FeO	10.50	5.50
CaO	7.81	7.94
MgO	6.54	7.50
Na_2O	1.96	2.59
K_2O	0.34	0.56
H_2O	3.99	4.09
CO_2	0.08	5.38
Total	100.57	100.39

TiO_2 not determined.
Powder dried at 105° C.

The changes here are at once seen to be due (1) to the total removal of the iron ores (loss of iron); (2) to the production of carbonates (gain of CO_2, carbonatization); and (3) to the increase in the amount of chlorite, (increase of H_2O, hydration).

Toward the eastern end of the small cove the dark-green schistose rocks appear to pass by insensible gradations into exactly similar ones of a lighter color. No. 11015, one of these, is seen under the microscope to be a very schistose aggregate of extremely pale chlorite and quartz grains. There is a little calcite here present and occasional scales of sericite. The rutile, in very minute and sharp crystals, is here crowded into long bands and stringers which follow the schistosity of the rock and give the thin section a pronounced "Flaser" structure.

No. 11016, from the extreme eastern corner of this cove, represents a band of light colored brownish rocks with a perfectly developed schistose structure and a grain somewhat resembling that of wood. These

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stand nearly vertical, though some dip from 65° to 70° N. 20° W. Their strike is turned from that of the other rocks here (S. 70° E) some 30° to 40°, so that they now strike N. 70° E. Under the microscope this rock is seen to have essentially the same structure and composition as the last. The main difference between them is that the present specimen has a brown chlorite instead of a green one. This it is that imparts the peculiar color to the rock in the hand-specimen. There is also more calcite in this rock than in the other. It would seem, along with No. 11011 above described, to represent the most profoundly metamorphosed phases of the massive rocks at Lower Quinnesec Falls. The original constituents have undergone an alteration to chlorite, quartz, carbonates, and rutile. The iron has largely disappeared, and the crystallization of the new components under lateral pressure has produced a very pronounced schistose structure.

No. 11023, from the upper end of the breakwater, above the falls (Wisconsin side), is very closely allied to the two specimens last described. It is a grayish schist, with the prevailing strike, but everywhere seamed with transverse cross-gashes, which are, for the most part, filled with infiltrated quartz. There seems to be little doubt from a field examination, that this rock is continuous with the massive diabase (No. 11021) in the same way that the last mentioned specimens are continuous with Nos. 11012 and 11013. The massive green rock (No. 11021) is exposed a very short distance to the west of it, where it also is filled with seams and cross-gashes, which appear to have been squeezed open by lateral pressure. From this point the transition to the gray schistose rock is a very gradual one. The latter rock has no regular bedding but only a cleavage in one direction. This causes it to break out in angular prisms. The rock is everywhere fissured, slickensided, and filled with infiltration quartz, as evidence of the enormous pressure to which it has been subjected. Under the microscope it is much like No. 11016. There is the same quartz mosaic, pale chlorite and strings of rutile needles, arranged so as to produce a decided schistose structure. There is, however, in this rock considerably more calcite and an additional feature in the way of remains of former feldspar crystals. These are considerably altered, and appear to be changing to a mass quite like that which composes the rest of the rock. In fact, this has gone so far that it is almost impossible to distinguish these feldspars in ordinary light, although their outline and nature become very apparent between crossed nicols. They are arranged without reference to the present schistose structure of the rock, and evidently represent original constituents of the rock from which the present schist has been derived.

In place of the above-described transition from massive to schistose rocks along a line—normal to the strike—there is in many instances the still more conclusive proof to be found in this same transition around ellipsoidal or lenticular cores of massive rocks. Such masses grow gradually schistose around their periphery and pass into schists which ap-

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pear to wind around and enclose them, but which, in reality, have been formed out of their own substance. An admirable example may be seen just at the Wisconsin edge of the river at the foot of Lower Quinnesec Falls. This is a lenticular mass of massive greenstone about eight feet in its longest diameter. This grades insensibly around its edge, into dark green schists, differing only in their structure from the central rock. Four specimens (Nos. 11017, 11018, 11019, and 11020) were collected to illustrate this passage. The most interior and massive one (No. 11017), although to all appearances quite compact, is found upon a microscopic examination to be wholly altered mineralogically. The bisilicate constituents are now represented only by a light emerald-green, pleochroic mineral, which, in spite of its comparatively strong action upon polarized light, is probably chlorite. This frequently contains sharp epidote crystals. The feldspar, while retaining much of its original form, is composed either of a gray, opaque saussurite or of a fine mosaic of quartz and albite grains and a great deal of calcite.

The extremely altered condition of the central portion of this core is perhaps rather advantageous than otherwise, for, while there can be no doubt as to its original character, the transition to the schists is seen to take place wholly by a change in structure, without further mineralogical alteration.

No. 11018, taken from a place where indications of a schistose structure are already quite apparent, shows just the same mineral components as the last. The chlorite scales, however, have assumed a decidedly parallel arrangement, which is followed, to a less extent, by the fine mosaic of quartz and albite grains. The calcite is better crystallized, and forms larger individuals. There are also present some minute scales of a deep red iron oxide, probably göthite, or limonite. The gray saussurite is likewise common.

No. 11019, in which the schistose structure is still more apparent, shows the same components as the others. The parallel arrangement of the chlorite is still more pronounced and the calcite still better crystallized. Strangely enough, we meet here, in a very schistose rock, better preserved feldspar crystals than can be found in the more massive greenstone, with which it is so intimately connected. This is but one more instance of the remarkable rule set down on p. 88, and alluded to several times already. This thin section (No. 11019) exhibits feldspars so well preserved that only occasional epidote crystals are developed in them. There is also to be seen a remarkably good example of the change of pyrite to iron hydroxide.

No. 11020 represents the extreme member of this series. It is a typical chlorite schist, in which alternating and interlacing areas of pale green chlorite and a fine quartz albite mosaic may be seen. In both a highly developed schistosity is produced by the parallel arrangement of the components. The grain of this rock, in so far as it is due to these alternating areas, appears somewhat coarser than in the less altered forms.

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The chlorite, if it be examined with a higher magnifying power, is seen to be filled with irregular spots of a reddish brown color, which feebly polarize, and seem to be the remains of former feldspar crystals. Rutile in grains or sharp crystal forms is also present.

The fine mosaic which composes the other areas, contains, in addition to the quartz and albite grains, calcite and chlorite in small, elongated scales.

A careful field examination shows conclusively that the four specimens here described (Nos. 11017 to 11020), represent only different forms of the same rock. In fact, the mineral composition is identical for all, although the most massive form is beyond all doubt an altered diabase, while the exterior bands, which surround this core are just as truly examples of a typical chlorite schist.

No. 11048 is a specimen of the massive, dark green rock which has been blasted out behind the shanty on the Michigan side of Lower Quinnesec Falls. A microscopic examination shows at once that this rock was originally a diabase, although its present constituents are for the most part secondary. The shapes of the original minerals are indistinctly outlined, and so the structure of the rock is preserved. There is now present a pale green hornblende, probably secondary to pyroxene, although no traces of this mineral are preserved; epidote, chlorite, saussurite and leucoxene in zones around the titanic iron. The feldspar has rarely changed to the opaque, gray saussurite, but is replaced for the most part by a mass of sharply defined epidote crystals. Where the feldspar and hornblende have jointly contributed to the formation of secondary products, we have the chlorite epidote aggregate as a result. A little secondary quartz is also observable.

The two remaining specimens examined from Lower Quinnesec Falls (Nos. 11101 and 11102) were collected on the Michigan side of the river above the fall, from two points designated by *u* and *w* respectively on Major Brooks's map. They exhibit in a marked degree the effects of stretching upon massive greenstones. If a rock mass were subjected to a great lateral pressure when it was free to expand in a direction perpendicular to that in which the pressure acted, it would appear as though it had been subjected to a strain or tension in the direction along which it was free to move. There would be a breaking and pulling out of the individual minerals into parallel bands along the line of expansion or apparent stretching. This phenomenon is very admirably displayed in these two specimens.

No. 11102 is the coarser grained of the two rocks and shows its structure best when the microscopic section is examined with a pocket-lens. Its appearance, as seen under a low power of the microscope, is portrayed in Pl. XI, fig. 2. One of the most important of the original constituents of this rock was a triclinic feldspar in large sized individuals. These are now fissured in a direction normal to the stretching and their fragments are separated in a most striking manner. The

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interstices are filled with long, chlorite scales arranged perpendicular to the walls of the fissures; more rarely calcite replaces this chlorite. Here again we have clear evidence that the chemical change in the feldspars of rocks which have been subjected to great mechanical action, is comparatively slight. The feldspars of this rock are scarcely altered except by being broken or crushed.

The grains of original quartz in this rock have suffered the usual deformation, being rarely broken but more frequently in a state of tension which imparts to them an undulatory extinction.

Very finely fibrous, dark green actinolite is quite abundant, representing some other bisilicate constituent (either pyroxene or compact hornblende) all traces of which have now disappeared. The fibers are sometimes parallel over considerable areas, sometimes crowded together into a confused and matted mass. They themselves show no evidence of pressure and hence must have originated during the action of the pressure or subsequent to it. The former is the more probable and the pressure may have been the very cause to which the hornblende owes its origin, as I suggested in a former paper.[1]

None of the constituents displays the effects of the stretching action to which this rock has been subjected more distinctly than the ilmenite. This mineral is abundant in grains of considerable size, all of which have been irregularly fissured in a direction transverse to the tension and the fragments separated, exactly like those of the feldspar.[2] (See Pl. XI, fig. 2.) The absence of leucoxene around these grains may indicate that in this case also the chemical action is inversely proportional to the mechanical.

No. 11101 is a very similar rock of a finer grain, in which the effects of stretching are not so apparent. We therefore find the chemical alteration of the feldspar proportionately greater. This mineral is not so much broken as in the specimen last described, but it is filled with secondary crystallizations of chlorite and epidote. The ilmenite is broken and stretched in the manner described in the preceding specimen, though to a less degree. The separated ilmenite fragments, however, in this case present a contrast to the others, in having leucoxene quite abundantly developed around them. The hornblende of this rock is both brown and green; each variety is dark colored and intensely pleochroic. Most of it is fibrous, the fibers following in their arrangement the general direction of the foliation.

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[1] Am. Jour. Sci., 3d series, Oct., 1884, vol. 28, p. 266.

[2] A. Schenck describes and figures exactly this phenomenon in the schistose diabases of the upper Ruhr Valley. Inaugural Dissertation, Bonn, 1884, p. 55.

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CHAPTER III.

GREENSTONE BELTS OF THE MENOMINEE DISTRICT—(Continued).

UPPER OR BIG QUINNESEC FALLS.

About 3½ miles above Lower Quinnesec Falls, described in the preceding chapter, the course of the Menominee River is again interrupted by extensive rock exposures, which skirt the banks for nearly 2 miles. The upper mile of this distance is a high, rocky gorge, known as the "Horse Race," through which the water rushes and tumbles in a foaming rapid. The current then flows more quietly through a broader, though still rocky channel, for half a mile, when it suddenly plunges over a fall of considerable height and beauty, known as Upper or Big Quinnesec.[1]

Below this fall the stream broadens into a wide basin, which is also bordered by rocky shores.

The continuous exposure of Upper Quinnesec Falls is, therefore, separable into three naturally distinct divisions. These divisions are, moreover, each characterized by a different kind of rock; a fact which serves to distinguish them almost as sharply as their physical conformation. (See map, Pl. V.)

The rocks which are exposed along the basin belong, for the most part, to the class of dark, more or less schistose greenstones, similar to those occurring at Lower Quinnesec Falls. These were once diabases rich in iron, which have produced amphibolitic and chloritic schists of a deep green color.

The actual barrier at Upper Quinnesec Falls is, on the other hand, composed of the light colored type of greenstone with a distinctly granular structure, like that already described as occurring at both the Sturgeon and Lower Quinnesec Falls. This is also the commonest rock for the half mile above the falls, before the rapid is reached. It is deserving of careful study on account of the transition which it presents into light colored sericite schists.

The rock which forms the steep walls of the gorge known as the Horse Race is of still a different type. It will receive a separate treatment, as it is quite unlike anything observed elsewhere in the Menominee Valley.

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[1] This name is a corruption of the Chippewa *Bequenesec* which is spelled by H. Credner in his description of this locality as *Bekuenesek*. (Neues Jahrbuch für Mineral., 1870, p. 971.)

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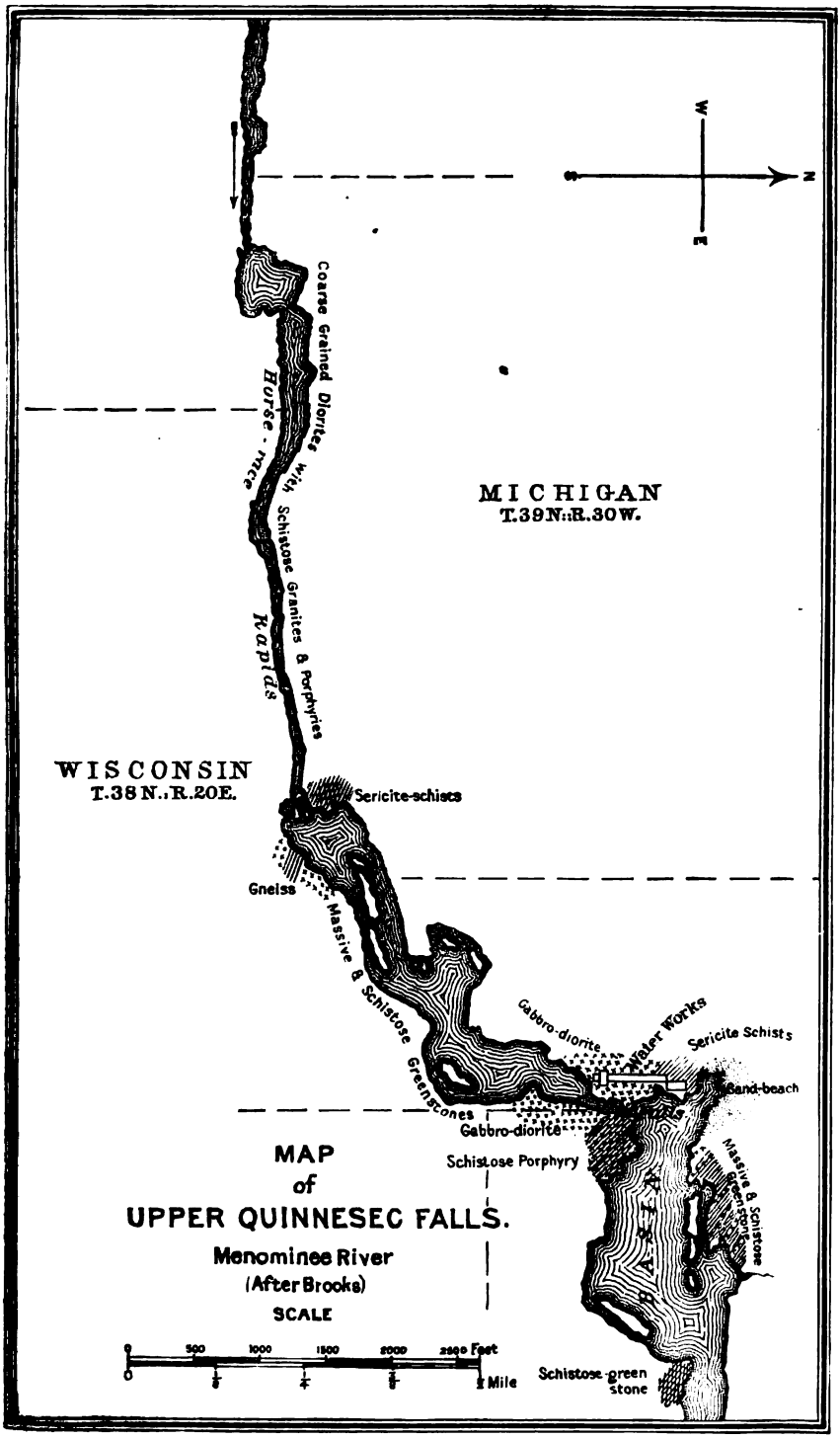

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Finally bands of certain acid rocks—granites, gneisses, and schistose porphyries—occur in the greenstones both at the fall and along the Horse Race. They appear to stand in the closest genetic relation both to each other and to the great granite area which lies south of the river and approaches it at this point more nearly than at any other.

We may, therefore, consider the rocks of Upper or Big Quinnesec Falls under the four following heads:

(1) The dark colored greenstones of the basin.
(2) The light colored greenstones at the falls.
(3) The coarse grained diorites of the Horse Race.
(4) The acid rocks, both massive and schistose.

THE DARK COLORED GREENSTONES OF THE BASIN.

At the lower (eastern) extremity of the basin, below Upper Quinnesec Falls, is an exposure of greenstone which juts into the river from the Wisconsin side. It is of a uniformly green color and, for the most part, massive, although schistose portions are not infrequent, which have the prevailing strike, N. 70° W., and stand nearly vertical. These schistose bands have in the field every appearance of being secondary since they are only locally developed and grade imperceptibly into the massive rock. A specimen from this locality, No. 11049, when examined microscopically, appears to be very similar to a rock already described from the Lower Falls (No. 11048). The process of alteration there indicated, however, has here progressed much further. There is every reason to believe that this rock, like the other, was once a diabase; and yet, in this case, all traces both of the original structure and of the original constituents have disappeared. The feldspar substance is completely replaced by a confused network of epidote needles, or of these mixed with chlorite; some rather compact, green hornblende still remains, but this mineral is rapidly disappearing, and the manner in which, jointly with the feldspar, it furnishes the materials out of which the chlorite-epidote aggregate is formed is here very instructively displayed. In fact, no other rock showed this characteristic form of alteration as well as this one, and it was therefore selected to furnish the illustration. (See Pl. XI, fig. 1.) The titanic iron is here in the form of small grains, accompanied by leucoxene.[1]

On the southern or Wisconsin side of this basin there are no more important exposures of the dark colored greenstones. On the Michigan side, however, such exposures are abundant and have been indicated on Maj. Brooks's map as the points *z*, *aa*, *bb*, and *cc*.[2]

Two suites of specimens collected at these points, one by Prof. Irving

[1] Slide No. 931 of the collection of the Lake Superior Division of the U. S. Geological Survey was prepared from a specimen collected by Prof. R. D. Irving west of the above, among the light colored greenstones. It is of great interest in this connection because its feldspar is quite well preserved and shows in a most unmistakable manner the ophitic structure of the diabases. In other respects, especially in the character and abundance of the epidote-chlorite aggregate, it is quite identical with No. 11049.

[2] Geol. Wisconsin, vol. 3, Pl. 3, p. 474.

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and the other by the writer, were studied. The rocks all exhibit the effects of extreme mechanical action upon their constituents, which has so far obliterated their original structure as to render their true character doubtful. They agree in being composed of different proportions of a much crushed and altered, reddish brown feldspar and a pale green mass consisting of chlorite and quartz. The latter aggregate is of secondary origin and imparts a cleavage to the rock, since the chlorite flakes are all arranged in one direction.

No. 4162, from Prof. Irving's collection, was the only specimen studied microscopically from point *z*. It is composed mostly of feldspar, and has, therefore, a reddish color. This constituent is intensely crushed and its substance is so highly altered as to appear to grade imperceptibly into the quartz chlorite matrix, which is present in small amount between its fragments. Scattered through this mass in the direction of its foliation are long lines of some opaque iron oxide, accompanied by very minute though sharply defined crystals and twins of rutile (Thonschiefernadeln), like those represented in Fig. 12, p. 106. In some cases the iron oxide is absent, and these dark bands may be seen with a high magnifying power to be made up entirely of the closely clustered rutile crystals.

Nos. 4163 and 11070 are both from Brooks's point *aa*, which he describes (loc. cit.) as composed of a "chloritic greenstone schist, with pinkish grains of feldspar (Schalstein?)."

The first of these sections belongs to Professor Irving's collection, and exhibits under the microscope the effects of the crushing and stretching in a very marked degree. Its structure resembles that of specimen No. 11102 from the lower Quinnesec Fall, described on p. 94, and represented in Pl. XI, fig 1. White and reddish feldspar crystals, quartz grains, and opaque black spots of iron oxide are imbedded in a secondary matrix consisting of chlorite, quartz, and epidote. No trace of an original bisilicate now remains. All of the older components, especially the feldspar and iron oxide, are much broken and their fragments are separated in one uniform direction corresponding to the foliation of the rock; but yet the fragments which once belonged together can still be recognized. The feldspar substance, in spite of the intense crushing, is still remarkably fresh and its twinning striation distinct. Lath-shaped forms, like those of diabase, are present, though all traces of the original rock structure have disappeared. The opaque grains of iron oxide (magnetite) are broken and pulled apart like the feldspar and can be seen with a high magnifying power to be fringed with minute and imperfectly formed rutile crystals. Sharply defined octahedra of magnetite—evidently of secondary origin, as they never exhibit any traces of mechanical action—are also scattered through the chlorite, and in some cases these octahedra are crowded together with little rutile crystals, both looking as though they had resulted from the alteration of some preexisting mineral.

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No. 11070, collected by the writer from the same locality as the last (Brooks's point *aa*), possesses a similar character, though with certain important differences. The hand-specimen is dark green in color and decidedly schistose. Under the microscope it is seen to be essentially the same rock as that last described, but in an even more advanced stage of alteration. The fragments of reddish feldspar, which can still be seen to belong together, are here, as before, separated in the direction of the foliation, while the spaces between them are filled with chlorite flakes and quartz grains. The feature of particular interest in this specimen is, however, the abundance of its rutile and the constant and close association of this mineral with the black iron oxide. This association, as well as the general appearance of this rock under the microscope, is represented in Pl. XIII, fig. 2. The opaque, black grains, which in reflected light can be seen to be intergrown with a considerable proportion of pyrite, are surrounded by a border of stout, brownish yellow needles, averaging from 0.1 to 0.05^{mm} in length by from 0.02 to 0.01^{mm} in width. They are crowded closely together and are often parallel to the external edges of the grains. Not infrequently, also, they exhibit a regularity of arrangement, crossing each other at angles approaching 60° and 120°. It will be readily seen, however, that in a random section of the rock it is impossible to decide whether these are exactly the angles or whether they are the angles 54° 43′ and 65° 35′ (with their supplements, 125° 17′ and 114° 25′), which von Lasaulx has shown are produced by the twinning of rutile, and characteristic of its network growth called as sagenite.[1] An isolation of these needles was made by dissolving all the other constituents of the rock in HCl and HF, for the purpose of obtaining material which might positively decide this point, but no definite results were obtained. The needles are for the most part irregular in their arrangement, and it still remains uncertain whether their occasional regularity is due to twinning or to some other cause.

A chemical examination of the isolated needles showed that they were composed of titanium oxide, while their crystallographic and optical properties observed under the microscope proved them to belong to the species rutile.

The fact that the black, opaque constituent of this rock is traversed by parallel cracks and fissures, often in sets intersecting at an angle of 60°, like those observed in titanic iron, taken in connection with the close relationship of the rock itself to the family of diabases, naturally led to the assumption that the iron oxide was ilmenite. Moreover, the similarity of the distribution of the rutile about the black cores to that of leucoxene about ilmenite crystals in the process of alteration—its presence as a continuous border and in every crack, while the black substance itself is quite free from the needles[2]—seemed further to indi-

[1] Zeitschr. für Kryst. u. Min., vol. 8, 1884, p. 56.

[2] This was shown, not merely by the absence of the larger needles which, if they were present, must have appeared through the black substance of the iron oxide in the thin section, but also by slowly dissolving away the oxide with HCl under the microscope and the failure thus to disclose any smaller crystals of rutile, which might have been wholly inclosed within the black ore.

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cate the secondary origin of the rutile out of the ilmenite. This is the view that was at first taken by the writer and published by him in a letter to the Neues Jahrbuch für Mineralogie, etc., 1887, vol. 2, p. 263. In a subsequent paper on the same rock,[1] Prof. Cathrein of Karlsruhe showed, among other points which he considered as objections to the secondary origin of the rutile, that the black iron oxide was not ilmenite at all, but magnetite. This determination has since been confirmed by a careful chemical examination made at my request by Prof. S. L. Penfield, of the Sheffield Scientific School at New Haven.

A very similar occurrence of rutile needles, though inferior in size to those here described, has been observed by Cathrein in the leucoxene border which surrounds both ilmenite[2] and titaniferous magnetite[3] in certain Tyrolese rocks. Dr. J. Blaas also encountered the same kind of a network of rutile crystals in a quartz phyllite from the neighborhood of Innsbruck, but in this case it was unaccompanied by any opaque ore.[4] In none of the instances observed by him does Cathrein consider the rutile as even possibly a secondary product. On the other hand, he thinks that the little needles were formed simultaneously with the ilmenite or magnetite, and that they have always existed in their present form within the iron oxide, until more or less completely liberated by the solution and removal of the latter.

In his article on the Quinnesec rock above cited, none of the points insisted upon by Cathrein appear to militate against the secondary origin of the rutile, except the last. As has been stated above, it is impossible in a random section to determine with certainty whether the needles intersect at angles of exactly 60° and 120°, or at those so nearly like them produced by twinning. But whichever be true, it is certain that a large majority of the needles are quite irregular in their arrangement. The discovery, however, that the black iron oxide which accompanies the rutile is not ilmenite but a magnetite almost free from titanium, seems at first altogether incompatible with the idea that the rutile is a secondary derivative from ilmenite. Nevertheless, a continued and repeated study of a large number of thin sections of this rock have served to convince the writer more and more that the rutile was at least not a constituent of the rock in its original state. The rutile aggregates are never drawn out in the direction of the stretching, as are all of the original constituents, notably the feldspar, and as they must have been had they always been present in the rock. It is necessary, therefore, to assume that they originated subsequent to, or, more probably, at the time of the metamorphism.

The constant and intimate connection between the rutile and the magnetite clearly shows that they are in some way genetically related. Opposed to the supposition that they were originally parallel inter-

[1] Neues Jahrbuch für Mineral., etc., 1888, vol. 2, pp. 151-165.
[2] Zeitschr. für Kryst. u. Min., vol. 6, 1882, p. 248.
[3] Ibid., vol. 8, 1884, p. 321.
[4] Tschermak's min. u. petrog. Mittheil., vol. 4, 1882, p. 514, fig. 2.

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growths, is, however, the fact that the rutile needles never occur within the magnetite, now present. The rutile forms a border around the black areas, which themselves frequently show a sharp crystal outline, difficult to reconcile with the idea that they have been partially dissolved so as to reveal the rutile which once existed within them. In one instance, indeed, an aggregate consisting of rutile needles and sharp octahedra of magnetite was observed, but this is exceptional. On the other hand, it may often be clearly seen that the magnetite has, to a greater or less degree, been removed by solution; but in all such cases the place that it once occupied exists within the fringe of rutile, but is itself wholly free from the needles. This space is often filled with calcite, or some similar carbonate, in slightly radiating tufts.

All of these observations seem to point to a contemporary origin for both the magnetite and rutile from some preexisting mineral, which in the present case may very probably have been ilmenite.

The change of hematite into magnetite is one which has been often observed. Roth[1] quotes descriptions of this alteration from Breithaupt, Volger, Peters, vom Rath, Petersen, Döll, Grattarola, and Zeparovich. There seems to be no reason why the corresponding titaniferous compound, ilmenite, should not also pass over into magnetite with the separation of its titanium in the form which is most stable for the conditions then prevailing.

Rutile is well known to be widely distributed in microscopic crystals through schists which have resulted from the regional metamorphism of both sedimentary and eruptive rocks. It must therefore be a compound well in accord with the conditions producing metamorphism.

The common presence of rutile needles in diabase rocks which have been intensely altered by pressure, and its absence in their unaltered forms, in connection with the fact that the original ilmenite disappears in proportion as the rutile is developed, has inclined such eminent petrographers as Lossen and Rosenbusch to the supposition that the latter mineral has originated from an alteration of the former. This hypothesis has derived much support from observations made in many of the Lake Superior greenstone schists which are altered diabases. In case of the particular rock under discussion, it is impossible to prove with the material now in hand that the magnetite and associated rutile have resulted from preexisting ilmenite, but in light of all that we know of this and other occurrences, it seems to the writer that such an origin is, to say the least, not at all improbable. Whether or not such an alteration as that here suggested really takes place in the ilmenite of diabase when this rock undergoes dynamic metamorphism to chloritic schists must remain for future investigations to decide.

Nos. 4164 and 4165, from Prof. Irving's collection, show the same rock as the two specimens last described in a yet more advanced stage of alteration. Both have become typical chlorite schists, composed

[1] Allgemeine und chemische Geologie, vol. 1, 1879, p. 97.

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mostly of chlorite, quartz, and iron hydroxide. The structure is now finely parallel and schistose, not the least trace of the original structure remaining. In No. 4165, which is the darker colored of the two, leaflets of a colorless mica (sericite) are abundant.

No. 11072, collected from Brooks's point *cc*, is a dark green rock, which is seen with the unaided eye to be traversed by numerous fibrous veins of a paler green color. Under the microscope the section of this rock shows principally ragged areas of green hornblende, inclosing isolated crystals of a mineral, which agrees more closely in its physical properties with zoisite than with any other; i. e., there are colorless rectangular sections with a cleavage parallel to the longest axis, and a cross-parting in the direction perpendicular to this. In polarized light these sections show pale, bluish gray interference colors, parallel extinction, and a biaxial figure. The fibrous veins, which compose a considerable proportion of the rock, are made up of zoisite individuals arranged perpendicular to the walls of the vein, and of fibrous hornblende, which often penetrates the former mineral in fine asbestiform needles.

THE LIGHT COLORED GREENSTONE AT UPPER QUINNESEC FALLS.

The speckled rock which forms the barrier at Upper Quinnesec Falls, is a very typical representative of the light colored greenstones of the Menominee region. It has a strong macroscopical resemblance to the rocks of this type already described from Sturgeon Falls and Lower Quinnesec Falls, but is more attractive in appearance than any of them. In the field it appears to be a medium grained aggregate of a white, opaque feldspar, in which, however, glistening, striated surfaces are by no means rare, and a grayish green mineral with a half metallic luster on its cleavage planes. The deceptive appearance of this mineral is the reason why Prof. Hermann Credner calls this rock (which he described as early as 1870) a diabase with a decided resemblance to a gabbro.[1]

This mineral does, indeed, show the most striking macroscopical similarity to the diallage of some of the Volpersdorf and Italian gabbros; but in spite of this fact, the most careful microscopical examination of many different specimens—the freshest that could be discovered—failed to disclose a trace of pyroxene. This result is the more surprising as the rock appears even fresher than that at Sturgeon Falls in which considerable pale diallage still remains. The microscope, however, shows that the rock at Upper Quinnesec Falls is the more altered of the two.

No. 11054, collected on the Wisconsin side of the river, directly at the fall, may be regarded as a typical specimen of the perfectly massive

[1] In speaking of this constituent he says: "Er [der Augit] bildet kurzsäulenförmige, zu krystallinischen Partien verwachsene Individuen, an denen orthodiagonale Spaltungsflächen mit halbmetallischem Glanze besonders deutlich hervortreten. Dadurch erhält das Gestein eine Aehnlichkeit mit Gabbro, selbst mit Hypersthenit." (Neues Jahrbuch für Mineral., 1870, p. 972.) Professor Pumpelly also says that this rock is identical with that of Sturgeon Falls. (Geol. Wisconsin, Vol. 3, p. 564.)

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rock. Its microscopical appearance is represented in Plate X, fig. 1. The hornblende is mostly of a very pale color and more or less fibrous in structure. It has every appearance of being secondary, and yet in every case where it can be traced into a more compact mineral this is also a hornblende of a dark green or brown color. In many instances the hornblende is bent and curved, as diallage is so apt to be (see right side of the plate); but the most striking peculiarity of this hornblende and the one most like diallage is its very perfect parting, parallel to the orthopinacoid (100). This very unusual feature is apparently confined to the paler, and probably secondary hornblende. It stops abruptly on the edge of the compact, more deeply colored variety, even where this is continuous with the lighter kind (Plate X, fig. 1).[1] This may indicate that the paler hornblende is secondary after diallage and therefore reproduces its orthopinacoidal parting, while the diallage was itself intergrown with an original compact hornblende which still remains. Aside from its characteristic prismatic cleavage, proof is furnished that this mineral is really hornblende by the fact that sections approximately perpendicular to the vertical axis, give, in converged polarized light, a bisectrix instead of an optical axis.

The feldspar of this rock is largely changed to opaque, gray saussurite. Portions of it, however, remain in an unaltered state. These have, even in the thinest sections, a pale brown color (Pl. X, fig. 1), and in thicker sections they are as dark as mahogany. This coloring is not due to inclusions from which the feldspar is surprisingly free, but to some unevenly distributed pigment whose nature it is far beyond the power of the microscope to reveal. With the exception of this color the feldspar is so remarkably fresh and clear as to make the impression at first glance that it must be of secondary origin. A slight examination, however, shows that the clear brown substance forms a peripheral zone about the saussuritized individuals; or where the whole crystal is unchanged, that it is bent, broken, or faulted in a manner inconsistent with any supposition of secondary origin. Here again we have additional, and, indeed, most convincing evidence that the greater the mechanical action to which the feldspar has been subjected, the less chemical change it has undergone. (See above, p. 88.)

The other constituents of this rock are ilmenite, surrounded by a leucoxene border, and some secondary quartz, which is penetrated by most delicate fibers of hornblende.

The analysis of this rock in column I of the following table was made by Mr. R. B. Riggs:

[1] It is interesting to note, in this connection, the recent observation of Cathrein that the hornblende of Rasta in the Tyrol has a perfectly developed parting due to very narrow twinning-lamellæ which run parallel to the orthopinacoid. (Zeitschr. für Kryst. u. Min., vol. 12, p. 12.) Whether the above-mentioned parting is due to the same cause or not, it is impossible, on account of the extreme narrowness of the parting-lines, to determine.

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	I.	II.	III.
Silica (SiO_2)	48.35	51.46	47.96
Alumina (Al_2O_3)	15.40	14.35	16.85
Ferric oxide (Fe_2O_3)	4.04	3.90	4.33
Ferrous oxide (FeO)	4.63	5.28	4.17
Lime (CaO)	10.38	9.08	13.25
Magnesia (MgO)	11.61	9.54	9.15
Soda (Na_2O)	1.87	2.92	1.25
Potash (K_2O)	.35	.24	.30
Water (H_2O)	3.60	3.30	2.89
Carbon dioxide (CO_2)	.08	.20	.08
Total	100.31	100.27	100.23

Dried at 105°.

The analyses of the two analogous rocks, Nos. 11171 (II) from Sturgeon Falls, and 11008 (III), from Lower Quinnesec Falls, are again cited from pp. 76 and 89, for comparison. The agreement between all three analyses is as close as could be expected for three different specimens of the same rockmass. In fact it is difficult to escape the conviction that the rocks from both Upper and Lower Quinnesec Falls, like that from Sturgeon Falls, were once diallage-plagioclase aggregates or gabbros; and yet if this be true, we are compelled to assume either that the original diallage passed by paramorphism into compact brown hornblende before reaching its present state; or that the original rock was a hornblende gabbro in which both bisilicate constituents passed finally into pale fibrous hornblende, although this process progressed much more slowly with the hornblende than with the pyroxene.

The feldspathic component of this rock (No. 11054) is determined by the analysis to be labradorite, as was also found to be the case in the corresponding specimens from the other localities.

Two other specimens of this same rock, No. 11061, from the Michigan side of the falls, and No. 11073, from a point above the falls, marked *p* on Major Brooks's map, are essentially the same as the one just described. Both are, however, more altered and both show, in a still greater degree, the effects of pressure upon the constituent minerals. In No. 11061 a good deal of quartz is present, always penetrated by delicate needles and tufts of hornblende. The largest areas of this quartz form a rather coarse grained mosaic and look as though they had been deposited as a pseudomorph after some former constituent. Some colorless chlorite is also present in this section, having been derived from the alteration of the hornblende. The feldspar of No. 11073 is colorless, and has been fissured, broken, and even crushed in a surprising manner. As a result, the saussuritization of this mineral has hardly more than commenced, in spite of the advanced state of alteration observable in the hornblende. One hornblende section in this slide, cut nearly perpendicular to the vertical axis, shows a very sharp line of demarcation between the interior, dark brown portion and the

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colorless peripheral zone. This resembles somewhat the secondary hornblende enlargements recently described by Van Hise,[1] but I can not regard this particular case as due to anything but exterior bleaching.

Nos. 11056 and 11057, from the Wisconsin side of the fall, illustrate the passage of this pale diorite into schistose varieties, as described at Lower Quinnesec Falls. The former specimen, though macroscopically still quite massive, has lost the distinctness of its structure. Under the microscope this is seen to be due to crushing and attendant chemical changes. The feldspar is almost pulverized, but has otherwise undergone but little change. A few of the larger crystals have been merely cracked and faulted as shown in Fig. 11. The hornblende is very largely changed to a colorless chlorite. Where one of the hornblende crystals has been broken and sheared, chlorite is seen to have been developed in parallel fibers. This furnishes an admirable microscopic illustration of how the schistose bands are formed by pressure in the rock-mass as a whole. (See also Fig. 22, p. 128.) Just below the falls this rock becomes broken, gashed, and seamed with narrow, parallel veins of lamellar minerals. These gradually increase to bands, which finally compose the main portion of the rock. There can remain no doubt in the mind of anyone who will carefully study this exposure, that these schistose bands have been produced in the massive rock by the action of pressure, along lines where there has been a shearing motion.

FIG. 11.—Faulted feldspar crystal in crushed greenstone (No. 11056) from Upper Quinnesec Falls. Nicols crossed; magnified 30 diameters.

No. 11057 is from one of the schistose bands in No. 11056. The microscope shows it to be composed of a fine mosaic of quartz and feldspar (?) grains, made schistose by parallel fibers of serpentine and chlorite.

At and just below the engine house on the Michigan side of Upper Quinnesec Falls is another exposure which illustrates the gradual passage of these light colored, massive greenstones, into silvery, hydrous schists, similar to those described as occurring just below Lower Quinnesec Falls.

No. 11065 is a very light colored, although nearly massive, rock, seen in situ in a wall behind the engine house. It is composed of much crushed and faulted feldspar of the above described brown variety, together with colorless isotropic chlorite. There is also some of the quartz albite mosaic, though this is not abundantly developed, with a little iron oxide. There is no parallelism in the arrangement of the constituents which would tend to produce a schistose structure.

[1] Am. Jour. Sci., 3d series vol., 33, 1887, p. 385.

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No. 11066 is from the same rock-wall as the last specimen and is undoubtedly continuous with it. It is decidedly schistose, and is composed wholly of a granular mosaic, with both sericite scales and a colorless chlorite. There are the finest microscopic rutile crystals in this rock that were encountered in any specimens from the Menominee region. These crystals are simple individuals, twins and trillings showing a great variety of form. A few are represented in the accompanying figure. They are grouped together or arranged in lines or strings which follow the direction of the schistosity. As in other similar instances before described from the Lower Falls, they appear to have originated from the alteration of the ilmenite of the massive rock.

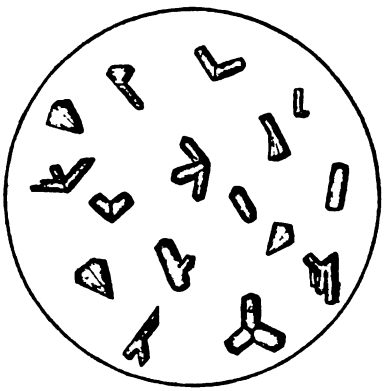

FIG. 12.—Rutile needles in No. 11056 magnified 350 diameters.

Just below the engine-house similar sericite schists are exposed (No. 11067 [1]) which contain green chlorite in spots and appear to grade into typical dark green chlorite schists (No. 11068). These rocks are mentioned by Major Brooks at the exposures marked on his map *x* and *y*[2]. These dark green schists are like those which originate from the alteration of the dark colored diabases, and their appearance probably marks the commencement of the belt of these rocks which skirts the basin below the Falls.

THE COARSE GRAINED DIORITES OF THE HORSE RACE.

The half mile of comparatively quiet water, navigable by a small boat or canoe, immediately above the Upper Quinnesec Falls is bordered mostly by massive or schistose greenstones of the dark type similar in all respects to the rocks of this kind which have been studied at several other localities on the Menominee River. They are interspersed with bands of gneissose rock, identical with those yet to be described.

The narrow gorge known as the Horse Race, through which the river flows for a mile or more, has, however, been excavated through rocks of a quite different character. These are for the most part coarse grained diorites, penetrated by bands of granitic and gneissic rocks which will receive special consideration in the following section.

Typical specimens of these coarse grained diorites are Nos. 11077 and 11093 from the Wisconsin, and Nos. 11182, 11183, 11185, and 11186 from the Michigan side of the rapids.

The macroscopical appearance of these rocks is often that of an almost

[1] This rock was called by H. Credner "talc-schist" in 1869 (Zeitschr. Deutsch. geol. Gesell., vol. 21, p. 529). It was described in 1876 by Wichmann, who gives seven reasons for regarding the sericite schists as of fragmental origin. (Geol. Wisconsin, vol. 3, p. 638.)

[2] Ibid., 1, pp. 473, 474.

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uniformly gray mass, in which the large and frequently glistening hornblende crystals are not at first glance very apparent. This color is due to the alteration of the feldspar, in which new minerals are largely developed. An opaque, white feldspar, or rather saussurite, is, however, often visible. This is sometimes in the form of rounded or oval areas which represent the centers of crystals that have turned gray around their edges; sometimes in the form of the original feldspar crystals themselves, and again in sharp contrast with the dark green hornblende. The grain of these rocks varies extremely, but is rarely fine. The form of the different constituents is always visible to the naked eye; and, in some instances (No. 11192), these measure from one to two inches in diameter.

Aside from the unusual coarseness of their grain, the rocks of the Horse Race differ from the other greenstones of the Menominee in frequently containing biotite. Another striking contrast is presented in the almost universal presence of talc. This mineral has without doubt originated from the hornblende, and has wandered from it into the feldspar. It is scattered everywhere through the rock in minute, silvery, glistening scales, and it coats all cracks and fissures. The surface of the hornblende crystals is also frequently spotted with it. The nature of this mineral as talc is easily determined by both optical and chemical means. Under the microscope it is of a pale green color, resembling muscovite in its cleavage and brilliant interference colors, but with a small optical angle and negative character. It is infusible and not attacked by acids, while microchemical tests show that it is destitute of both alumina and alkalies.

The structure of the Horse Race rocks is that of the second kind mentioned by Rosenbusch as occurring in diorite,[1] i. e., that conditioned by the feldspar having crystallized before the hornblende. The latter component is plainly allotrimorphic, like the pyroxene in diabase, while the feldspar has a well developed form of its own. (Pl. XII, fig. 2.) The hornblende, although comparatively compact and homogeneous over considerable areas, nevertheless conveys the impression of being of secondary origin. It has a pale green color, slightly darker toward the edge, and is externally frayed out into a fringe of radiating actinolite fibers, which wander along the cracks in the feldspar. (No. 11186; see Pl. XII, fig. 2.) In some sections—notably in No. 11185—large portions of the hornblende have become wholly changed to a felt-like network of minute fibers. These characters, together with the shape of the hornblende individuals, convey the impression that they have been derived from pyroxene. While, therefore, it is impossible to prove it with certainty, it is difficult to escape the conviction that these rocks were originally coarse grained gabbros or diabases.

The feldspar shows in almost every instance a broad twinning stria-

[1] Mikros. Physiog., 2d ed., vol. 2, p. 121.

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tion, although this is more or less obscured by chemical changes. In one specimen (No. 11182) there is a brown feldspar which is perfectly preserved around the periphery of the crystals, while their interior is changed to saussurite. In other cases (Nos. 11093 and 11185) the feldspar is largely changed to saussurite, with which is mingled a good deal of actinolite and some biotite. In the latter case clear areas of brilliantly polarizing talc are quite abundant. In Nos. 11077 and 11186 the white or colorless feldspar is comparatively well preserved, but it is filled with pale green actinolite needles and some little biotite, which appear to have wandered into it from the hornblende. In these rocks the amount of saussurite is inconsiderable.

Brown biotite is not infrequently an important constituent of these rocks. It is especially abundant in No. 11077. Although sparingly scattered through the feldspar like the actinolite, it is mainly to be found in close association with the hornblende, with which or out of which it seems to have been developed by secondary processes.

Other specimens represent exceptional varieties of the Horse Race diorites.

No. 11091, from the Wisconsin bank of the stream, shows the feldspar wholly changed to a compact aggregate of epidote grains.[1] The hornblende, which is in sharp crystals, presents its usual appearance and characteristics. The epidote is so light colored that it might easily be mistaken at first glance for feldspar in the hand-specimen. The microscope, however, at once shows its true character. The interference colors of the closely interlocking grains present a brilliant appearance. No trace of the original feldspar remains. Only an occasional grain of calcite or quartz interrupts the continuity of the epidote. Epidote is not an unusual secondary product in feldspar, although such perfect pseudomorphs of this mineral as are here present are rare.[2]

Still other specimens show, in a marked degree, the effects of dynamic metamorphism upon the Horse Race rocks. No. 11189, from the head of the rapid, on the Michigan side, has a pronounced gneissic structure. Its hornblende is of the usual character, sometimes in compact crystalloids of large size, sometimes in a fibrous aggregate, but almost always much twisted, bent, or broken. The feldspar, in some instances, is completely changed to an aggregate of epidote crystals, as in the rock last described; in others, it merely has minute, highly refracting epidote grains more or less abundantly developed in it (saussuritization). These are often accompanied by rhombic dodecahedra of a colorless garnet.[3] Other of the feldspar individuals show a mechanical rather than a chemical alteration. There is, in some cases, a

[1] A not unusual alteration according to Roth: Allgemeine und chemische Geologie, vol. 1, 1879, p. 321.

[2] Cohen mentions such a perfect transformation of feldspar to epidote in the diorite which forms the base of the island Palma. Neues Jahrbuch für Mineral., 1876, p. 751. Rosenbusch also mentions them in diorites from the Vosges Mountains. Mikros. Physiog., 2d ed., vol. 2, p. 103.

[3] Rosenbusch: Mikros. Physiog., 2d ed., vol. 2, p. 136. Paul Michael finds one of the two varieties of saussurite in the gabbro of Wojaleite, Fichtelgebirge, composed of a lime-alumina garnet and serpentine. Neues Jahrbuch für Mineral., 1888, vol. 1, p. 39.

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peripheral granulation (randliche kataklase) producing the "mortar structure" (Mörtel-Structur of Törnebohm). In other cases there is a complete reduction of the whole feldspar crystal to a granular mosaic, while in still others there is only a separation into large, interlocking, and but slightly disturbed areas. Fine veins of epidote not infrequently traverse these feldspar crystals. A point of mineralogical importance connected with this rock is the evidence it affords of the alteration of ilmenite into sphene. The usual alteration product of this mineral, leucoxene, is now generally believed to belong to this species, but it is rare to find the crystalline form of the sphene so typically developed as in this section. The mineral is of a grayish brown color and nearly opaque, like the secondary leucoxene which surrounds ilmenite. It polarizes with dull colors, but there is no mistaking its nature on account of its characteristic form. (Pl. XIII, fig. 1.)[1]

No. 11078, collected on the Wisconsin side of the river, just below the Horse Race, is perfectly continuous with No. 11077, above described, and represents a phase of this rock produced by the action of intense pressure. The hornblende is almost wholly changed to an aggregate of weakly polarizing fibers, which, according to the descriptions of Rosenbusch, are perhaps best regarded as of a serpentinous nature. These twine in and around the feldspar so as to produce a sort of "Flaser" structure. The feldspars themselves are sometimes reduced to a mosaic; but sometimes they have only a peripheral granulation. Much of the biotite of the unaltered rock remains among the alteration products of the hornblende. The iron ore has been drawn out into sinuous stringers which follow the direction of the foliation.

No. 11191 was taken from a wavy schistose, chloritic band on the Michigan side of the Horse Race. It has a strike 30° E. of N., and traverses a coarse grained massive greenstone, into which it passes by insensible gradations. In this rock there is considerable hornblende, which is seen in the process of transformation to a fibrous, yellow serpentine. The feldspar is of the reddish brown variety and has undergone granulation around the edge. This has been accompanied by the production of quartz and calcite. In a large area of the latter mineral there are crystals of a substance whose exact nature could not be determined. It has the bluish interference colors of zoisite, a parallel extinction and a biaxial interference figure. It is also changing to the same yellow serpentine as the hornblende. The sepentine penetrates and traverses it as it does crystals of olivine. Chlorite is also a frequent component of this rock.

Nos. 11080 and 11195 are exceptionally fine grained greenstones, the former from the foot and the latter from the head of the Horse Race. Both are composed essentially of actinolite, feldspar, quartz, and epidote, and resemble in their microscopical appearance and structure the

[1] Schenck observed the titanic iron entirely replaced by sphene in a schistose diabase from the upper Ruhr Valley. Inaugural Dissertation, Bonn, 1884, p. 57.

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typical so-called "crystalline schists." Still the former is massive and cuts across the strike of schistose rocks like a dike, while the latter is decidedly schistose. No. 11195 contains minute and sharp, dark brown sphene crystals, which appear to have originated, like those in No. 11189, from the alteration of ilmenite.

THE ACID ROCKS OF UPPER QUINNESEC FALLS AND THE HORSE RACE.

Among the rocks to be found in the neighborhood of the Upper Quinnesec Falls and Horse Race are those of an acid type. They occur in bands of varying width, which generally, but not always, conform to the foliation of the greenstones. These acid rocks are sometimes massive granites without a trace of schistose structure; sometimes gneisses with a "Flaser" or "Augen" structure, and sometimes finely banded and schistose rocks like the Saxon granulites. Whenever these bands show any indications of schistose structure this seems to be conformable to the cleavage of the adjoining greenstones, without reference to what the direction of the band itself may be. Inasmuch, however, as these two directions *generally* coincide, it is not common that the foliation of the acid bands makes any angle with their sides. Such instances were nevertheless occasionally found, and they have a very important bearing on the genesis of these rocks and on their relation to the greenstones which surround them.

An inspection of the published geological maps of the region south of Lake Superior[1] will show that immediately south of the portion of the Menominee River under discussion there is an enormous area of a typical granite. Major Brooks, in his report on the Menominee district, thinks that this granite may very possibly be of eruptive origin, but, whether so or not, that it certainly overlies and penetrates ("in veins") the upper members of the greenstone series.[2] Since, however, he regards the greenstones as occupying the upper portion of the Huronian formation, he is compelled to assume that the granite represents its youngest member and hence he designates it as the "Huronian granite." (See profile, Fig. 2.)

Without entering in this place into a discussion of the stratigraphical relationships of these rocks, it may at least be stated with certainty that this granite does penetrate the greenstones in the form of dikes and apophyses, especially where the main mass approaches nearest to the river. This point is about half a mile south of the Horse Race, as may be seen by Major Brooks's section and map of this region[3]. Here the typical, coarse grained and somewhat porphyritic granite appears in a high ridge.

The adjacent greenstones and greenstone schists do not here materially differ from those at Upper Quinnesec Falls. They strike nearly east

[1] Geol. Wisconsin, vol. 3, atlas, Pl. XXVIII; Mon. U. S. Geol. Survey, vol. 5, Pl. I; Fifth Ann. Rept. U. S. Geol. Survey, Pl. XXII.

[2] Geol. Wisconsin, vol. 3, pp. 452, 531, 719.

[3] Ibid., Pl. III, p. 472.

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and west and dip to the south. Near the granite contact they are filled with dikes of all sizes, evidently offshoots from the main granite mass (Nos. 11105 to 11107). These dikes, when small, are fine grained and felsitic, but when larger their texture is coarser and they have frequently a well developed schistose structure parallel to that of the adjoining schists. After a careful examination of this locality and of the exposures between it and the river, there is no doubt in the writer's mind that the granite, "Augengneiss," biotitic gneiss, and schistose porphyry (or "porphyroid," as Credner calls this rock) visible near the Upper Quinnesec Falls and along the Horse Race, are also dikes or aphophyses connected with the main southern granite area. The schistose or banded structure of these rocks, when such exists, is a secondary feature, produced by the same dynamic agencies which rendered the greenstones themselves schistose.

An intelligent study of these acid rocks should begin with an examination of the massive granite from the large area south of the Menominee. No. 11104 was collected near the contact, about half a mile south of the Horse Race, where, after appearing in numerous dikes in the greenstone, the solid mass of granite appears in an abrupt wall, trending N. 80° E. This rock appears in a hand-specimen to be a typical, coarse grained granitite, with a decided tendency to a porphyritic structure. The latter feature may, however, be due to the nearness of this locality to the contact. When examined under the microscope, the macroscopic diagnosis is found to be correct and several additional points of interest are brought to light. The oldest constituents are zircon and apatite; both quite abundant in the form usual in granitic rocks. Iron oxide seems to be almost absent as an original constituent, though it is found in some of the altered micas. The biotite, the only mica present, is not abundant. It is invariably bleached to a green color by the reduction of its iron to the ferrous state. It contains abundant inclusions of apatite, zircon (around which are pleochroic aureoles), and some secondary magnetite. No trace of either hornblende or pyroxene was observed. Sphene, however, is present, as are also a few sharp crystals of a dark grayish blue tourmaline. The principal interest of this rock attaches to its feldspar and quartz. They together make up nearly the whole mass and exhibit, in a remarkable degree, the effects of pressure. The feldspar is of three kinds: normal plagioclase (oligoclase), unstriated orthoclase, and microcline. The relationship of these species of feldspar is a suggestive one. Both the oligoclase and the orthoclase are always altered to a fine micaceous or kaolinitic product which is particularly abundant in the center of the crystals, a zone of the unaltered mineral being often preserved around the edge. The microcline, on the other hand, almost never shows any indication of alteration.

It is always clear and fresh in appearance, but its twinning lamellæ are bent or curved and bear every sign of having been secondarily developed.[1] In other words, we have here again, in the writer's opinion,

[1]Rosenbusch, Mikros. Physiog., 2d ed., vol. 2, p. 295.

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a striking example of the mechanical action apparent in the feldspar, being inversely proportional to the chemical action which has gone on in it. Original orthoclase has been converted partly into kaolin, partly into microcline, according to the way in which the action of the force manifested itself. The effect of the force which acted upon this rock is also apparent in other ways. The large original feldspar crystals show a peripheral granulation (see Chapter I, p. 49), and where they have been fissured their cracks are filled with a new crystallization of plagioclase, orthoclase, and quartz. None of these minerals shows any signs of chemical alteration and microcline is never to be found among them. Thus is produced a good example of what Törnebohm has called a mortar structure ("Mörtel-Structur")[1]. In this secondary cement-like aggregate, a micropegmatitic intergrowth of quartz and feldspar is quite common, and calcite, in good-sized individuals, is by no means rare.

The original quartz of this granite also shows many indications of having been squeezed. The crystals or grains often have an undulatory extinction, while larger grains are broken and the fragments are more or less displaced. Proof that these were not originally different grains is given in section No. 11104, where a small tourmaline crystal is broken and faulted just at the contact.[2] (See Fig. 13). No. 11105 is a specimen of the prevailing rock near the granite contact. This is a hornblende schist, composed mainly of irregular grains of dark green hornblende and quartz. There are beside some striated and some unstriated feldspars, a little sphene and an abundance of extremely sharp and clear epidote crystals. The banding of this rock is caused by the preponderance of hornblende in some layers and of quartz in others. Its strike is nearly east and west and its dip 75° to 80° to the south. Under the microscope all of the constituents by their extreme freshness and freedom from all inclusions convey the impression of being secondary crystallizations. The texture of the rock is granular, although the epidote is present either in exceedingly sharp crystals (which often pass unbroken from one quartz grain into another) or in much more minute, ovoid granules, forming the little, highly refracting particles which are so common in the crystalline schists. No. 11107 was taken from one of the wider of the numerous acid dikes which pene-

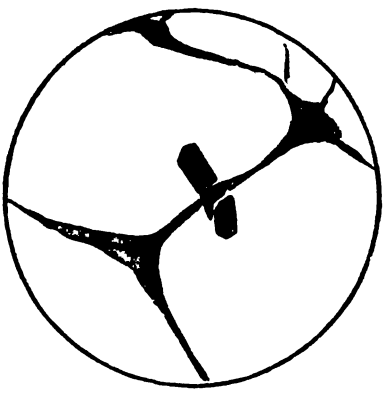

FIG. 13.—Broken tourmaline crystal proving the secondary fracture of the inclosing quartz grain, "Horse Race" granite. No. 11104.

[1] Några ord om granit och gneis. Geol. Fören. Stockholm Förhandl., 1880–'81, vol. 5, p. 233, (ref. Neues Jahrbuch für Mineral., 1881, vol. 2, Referate, p. 51; and Rosenbusch, Mikros. Physiog., 2d ed., vol. 2, p. 42.)

[2] Compare Dr. Chelius's remarks on the Hessian granite-porphyries, Notizblatt des Vereins für Erdkunde zu Darmstadt, 1883.

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trate the last described hornblende schist in the neighborhood of the granite contact. It has a decidedly gneissic structure parallel to the banding of the inclosing schist, which is here also the direction of this band or dike. The microscope shows that the mineral composition of this rock is identical with that of the coarse granite (No. 11104). There is the same zircon, sphene, and tourmaline associated with the biotite, feldspar, and quartz. The differences are the gneissic structure, fineness of grain and absence of all porphyritic structure in the dike rock, while none of its constituent minerals show the chemical alteration which has progressed so far in the massive granite. Both the biotite and the feldspar are quite fresh, the rich brown color of the former contrasting with green and bleached mica above described.

After the foregoing review of the character of the acid rocks at and near the granite contact, we are in a much better condition to understand the occurrence of the bands of gneiss and porphyroid near the Upper Quinnesec Falls, which were observed by Major Brooks and Prof. Pumpelly.[1] If we now examine some of the most typical of these exposures with care, we shall find that they are quite identical with the rocks which we have just been considering.

On the lower side of a small cove which indents the Wisconsin river bank immediately below the Horse Race there is a narrow band of acid rock well exposed on the shore. The center of this band is composed of a massive, gray colored, porphyritic rock resembling a granite (No. 11082). This grades on both sides imperceptibly into a well characterized, fine grained gneiss (No. 11085), which in places is so finely banded as to resemble some of the Saxon granulites (No. 11084). The foliation of this exposure is nearly vertical and seems to be quite parallel to the sides of the band, which itself makes only a slight angle with the cleavage of the adjoining greenstones.

No. 11082 was collected from the central and most massive portion of this acid band. Macroscopically the rock appears to be a typical granite porphyry, nor does the examination of a thin section with the microscope reveal anything opposed to this determination. The following analysis of the rock, however, made by Mr. R. B. Riggs, shows that this rock is in reality a diorite:

Silica (SiO_2)	54.83
Alumina (Al_2O_3)	25.49
Ferric oxide (Fe_2O_3)	1.61
Ferrous oxide (FeO)	1.65
Lime (CaO)	6.08
Magnesia (MgO)	1.96
Soda (Na_2O)	5.69
Potash (K_2O)	1.87
Water (H_2O)	1.18
Carbon dioxide (CO_2)	.18
Total	100.54

[1] Geol. Wisconsin, vol. 3, p. 474.

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The microscope discloses good-sized crystals of a striated and zonally formed feldspar embedded in a granular mosaic of clear, colorless, and unstriated grains associated with brown leaflet of biotite. Apatite, zircon, and a reddish pleochroic sphene are also present in small crystals. In spite of this rock showing no indication whatever of alteration, it contains calcite in considerable quantity. This mineral apparently penetrates and includes all the other constituents in a manner which has led Hawes,[1] Törnebohm,[2] and Chrustschoff,[3] to regard it under similar circumstances as a product of the original crystallization. In one section of the present rock sharply defined sphene crystals were observed wholly surrounded by the calcite. Nevertheless the presence of this carbonate in the fresh rock is to be explained, as Rosenbusch suggests, by the filling up of drusy or miarolitic cavities.[4]

The rock appears both macroscopically and microscopically to be a granite porphyry with a microgranitic groundmass. The analysis, however, shows it to be largely composed of a feldspar of the andesine series, and this is also indicated by a further examination. The colorless grains of the groundmass, in spite of their limpid character and superficial resemblance to quartz, give in converged polarized light the brush or hyperbola of a biaxial crystal. In the Thoulet solution the colorless portion of the powder fell between 2.683 and 2.650, a large proportion, however, being confined between the limits 2.668 and 2.659. A small proportion possessed exactly the specific gravity of quartz, so that it is impossible to say with certainty whether this mineral is present in the groundmass. The relative proportions of silica and alumina, however, as given by the analysis, make this improbable. We must describe this rock as a very pure type of a mica-diorite porphyry whose groundmass is composed of a mosaic of clear unstriated lime-soda feldspar, probably andesine.

The two specimens (Nos. 11084 and 11085), taken from the gneissic portion of this exposure, when seen under the microscope, closely resemble the groundmass of the diorite porphyry just described. The chief difference is in the banded appearance, produced by the parallel arrangement of the grains, and especially of the mica plates. This is most pronounced in No. 11084, where the mica is collected in certain layers and where there is also an alternation in the grain, some layers being coarser and others finer. Occasional tourmaline crystals are here associated with the zircon and apatite. Calcite also is present, as in the last described rock, but now it is in stringers and arranged, like all the other components, in the direction of the schistosity. No. 11085 has neither the calcite nor the tourmaline. Its most interesting feature is the presence of long strings of minute rutile crystals which appear to

[1] Geology of New Hampshire, vol. 3, Part IV; Mineralogy and Lithology, 1878, p. 208, Pl. XII, Fig. 1.
[2] Om Kalkgranit. Geol. Fören. Stockholm Förhandl., vol. 3, 1876, p. 210. Om Kalcithalt i graniter. Kong. Vetensk. ak. Förhandl., vol. 5, 1881, p. 233.
[3] Bull. Soc. Minéral. de France, vol. 8, 1885, p. 137.
[4] Mikros. Physiog., 2d ed., vol. 2, 1885, p. 34.

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have originated from the alteration of the biotite. No. 11079, collected from a narrow acid band slightly east of this exposure, is quite identical in both composition and structure with the two last mentioned rocks. There are here occasional remains of former porphyritic feldspar crystals which have been mostly destroyed by granulation. Tourmaline is quite abundant, as are also flakes of colorless but brightly polarizing sericite.

It will be seen that these rocks are quite the same as those found farther south at the granite contact. Along the whole extent of the Horse Race similar acid rocks are very abundant. They occur in bands varying from the finest seams to such as are many yards in width. While these as a rule follow the direction of the foliation of the greenstones, they by no means always do so. Their mode of occurrence often bears strong testimony to their intrusive nature, as may be seen from the following figures sketched at the head of the Horse Race on the Michigan side of the river.

Fig. 14.—Exposure on the edge of a small cove at the head of the Horse Race. Direction of the shading lines indicates the strike.

Fig. 14 shows two bands of gneiss, one parallel to the strike of the greenstones, the other cutting across it. In each the lamination of the acid rock coincides with that of the greenstones, without regard to the sides of the band. This would seem conclusive evidence of the secondary nature of the gneissic structure.

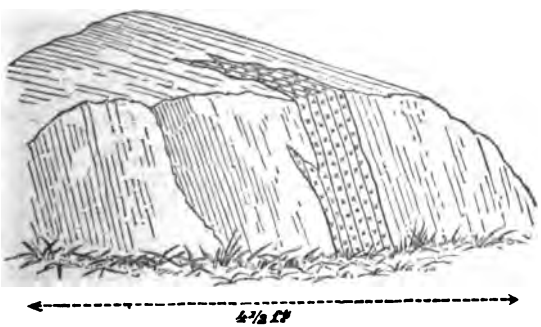

Fig. 15.—Foliated granite (gneiss) intrusive in greenstone. Head of the Horse Race.

Fig. 15 shows a band of gneiss which comes to an abrupt termination in the greenstone and which sends out apophyses into this, as only an intrusive dike would do.

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Fig. 16 shows an irregular area of gneiss penetrating the greenstone. The lines in the drawing indicate the direction of the foliation. This may be a cross-section of a laterally intrusive arm.

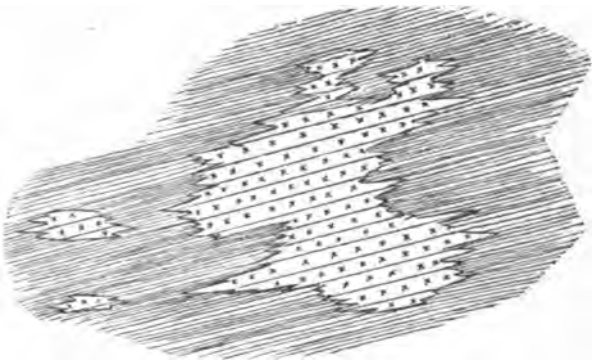

FIG. 16.—Foliated granite (gneiss) intrusive in greenstone. Head of the Horse Race.

Many other exposures might be selected to prove the intrusive nature of these acid rocks at the Upper Quinnesec Falls, but the ones already cited will suffice for the present purpose.

With respect to their structure, the acid rocks of the Upper Quinnesec Falls and Horse Race may be classified as follows:

I. Porphyritic:

Granite porphyry, represented by Nos. 11104, 11082, 11087, 11089, 11190.

Augen-Gneiss, represented by Nos. 11184, 11193 11196.

Schistose porphyry, represented by Nos. 11050, 11051, 11052, 11096.

II. Non-porphyritic:

Gneiss, represented by Nos. 11079, 11084, 11085, 11188.

Felsite, represented by No. 11071.

The main points of interest will now be stated with reference to each of these types in succession, although no further mention will be made of those specimens which have already been described, viz, Nos. 11104, 11082, 11084, 11085, 11079.

It is believed that the distinctive features of the schistose and banded rocks of this region have to a great extent been produced by secondary causes. An original porphyritic structure seems to have been very prevalent, if not universal, in all of these acid dikes. We are able to trace its gradual disappearance, and we find that this is proportional to the intensity of the dynamic action to which the particular rock has been subjected. The crushing or rubbing of the constituent minerals against one another has produced a peripheral granulation ("randliche Kataklase"). This has altered the porphyritic crystals into the eyes or "Augen" of the gneisses and schistose porphyries, as is shown in Pl. XV, fig. 1; and there seems no reason why its extreme application may not have changed a porphyritic rock to a felsite.

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Granite porphyry.—No. 11190, from the Michigan side of the Horse Race, near its center, is from a small area of acid rock exposed at the water's edge, which seems to be completely surrounded on the three other sides by diorite. It is porphyritic, but contains a very large proportion of feldspars (mostly striated) and comparatively little groundmass. This latter is so arranged as to produce a resemblance to the *mortar-structure*, and thus the rock approaches No. 11104, although all of its quartz is confined to the groundmass. Biotite is quite abundant. It contains fine pleochroic aureoles, and is frequently bleached to a pale green color.

Nos. 11087 and 11089, both from the Wisconsin bank of the Horse Race, are decidedly porphyritic. A fine grained granular groundmass is in sharp contrast to the well formed feldspar crystals. These are noticeable on account of their finely developed zonal structure, which is produced sometimes by a concentric arrangement of inclusions, sometimes by a variation of composition and extinction angles in different layers. The zonal structure of the feldspars in these rocks is as perfect as it is in the more modern andesites. The mica in No. 11087 is biotite of the usual character, but in No. 11089 muscovite is equally abundant, making this latter rock a true granite instead of a granitite. Some of this muscovite, at least, may be plainly seen to have originated from the alteration of the orthoclase. In many cases it lies in brilliantly polarizing flakes of considerable size, clustered together in the center of the orthoclase crystals, which portion always appears to be the most subject to alteration.

These rocks show to a moderate degree the effects of pressure which are most manifest in the porphyritic quartzes. These are much distorted and often broken and granulated, as shown in Pl. XV, fig. 2. It seems at first thought strange that the harder quartz should be more susceptible to pressure than the softer feldspar, and yet this is known to be a well established fact, as has been observed in Chapter I. The brittleness of the quartz causes it to break, where the feldspar is only bent or distorted, without rupture.

FIG. 17.—Orthite in granite. Horse Race Rapid. No. 11087. Magnified 80 diameters.

In some cases the feldspar, as well as the quartz, shows a slight peripheral granulation and passage into a mosaic, which can not be distinguished from the groundmass. This is in all instances, however, only incipient, while the main portion of the groundmass is an original feature of the rock.

In the granitites, Nos. 11087 and 11190 an unusual constituent is present. This is in sharp crystals of good size (2 by 3^{mm}) and has the shape of epidote. Its color is yellowish brown or greenish yellow.

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It seems to have undergone partial alteration, and agrees closely with the published descriptions of orthite (allanite).[1] The two crystals in section No. 11087, although by no means entirely changed, appear to be completely isotropic, a peculiarity especially mentioned by Rosenbusch as not uncommon to orthite.[2]

Augen-Gneiss.—The best example of this type is No. 11184, from the Michigan side of the Horse Race. With reference to this rock the following is extracted from the field notes made in July, 1885:

A short distance above the mouth of the Horse Race the ridge is cut by a ravine. Here, near the water's edge, are some beautifully porphyritic, red, acid rocks, occurring apparently as dikes in the greenstone. The direction of these dikes is quite irregular. Their width also varies continually. They contain a deep red feldspar, a white feldspar, and quartz in porphyritic crystals. When much of the first mentioned feldspar is present, the rock is very red; when it is absent it is gray. Both varieties may occur in the same specimen. These rocks show the effects of pressure very finely. The porphyritic crystals form "Augen," around which the groundmass bends. The direction of the banding when well marked appears to be parall l to the walls of the dikes. The "Augen" stand vertically.

Under the microscope the banded or gneissic structure of this rock is as well marked by the lenticular ("Flaser") arrangement of the mica as in the hand-specimen. Its most instructive feature is the formation of the eyes ("Augen") and the gradual disappearance of the large porphyritic feldspar crystals by peripheral granulation due to pressure. A typical example of this is represented in Pl. XV, fig. 1. Here it will be seen that a large porphyritic crystal of triclinic feldspar has been granulated on two opposite sides, corresponding to the direction of the schistosity, and that the material thus formed has been drawn out into a lenticular-shaped mass, with the remaining solid portion of the feldspar as its center. This forms the eye or "Auge" around which the groundmass is seen to curve. Such a structure has been described and figured by J. Lehmann[3] and others. It is important to observe that the secondary granulation has here produced a mosaic of *much coarser grain* than the surrounding groundmass. This corresponds to observations of Dr. Chelius, made on certain Hessian granite porphyries.[4]

No. 11196, from the head of the Horse Race, on the Michigan side, is described in the field notes as "a typical biotite gneiss with a wavy structure, the biotite lamellæ (secondary?) winding around the porphyritic crystals of feldspar and quartz." Under the microscope the groundmass is seen to be fine grained, and, to some extent at least, to have originated from the granulation of the porphyritic crystals, which exhibit this process in an admirable manner. Dark brown biotite and sphene are common. Zircon and apatite are also present. The quartz

[1] A. Sjögren, Geol. Fören. Stockholm Förhandl., vol. 3, 1876, p. 258, Törnebohm Under Vega-Expeditionen insamlade bergarter. Vega-Exped. vetensk. jakttagelser, VI, Stockholm, 1884, p. 124. Cross & Iddings, Am. Jour. Sci., 3d series, vol. 30, 1885, p. 108.

[2] Mikros. Physiog., 2d ed., vol. 1, p. 499.

[3] Untersuchungen über die Entstehung der altkrystallinischen Schiefergesteine. Bonn, 1884.

[4] Notizblatt des Vereins für Erdkunde zu Darmstadt, 4. Folge, 5 Heft., 1885, quoted by Rosenbusch, Mikros. Physiog., 2d ed., vol. 2, p. 294.

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is in large granular areas. Rows of fluid cavities traverse the grains and pass uninterruptedly from one to another.

The following analysis of this rock is also by Mr. R. B. Riggs:

Silica (SiO_2)	67.77
Alumina (Al_2O_3)	16.61
Ferric oxide (Fe_2O_3)	2.06
Ferrous oxide (FeO)	1.96
Lime (CaO)	1.87
Magnesia (MgO)	1.26
Soda (Na_2O)	4.35
Potash (K_2O)	2.35
Water (H_2O)	1.69
Carbon dioxide (CO_2)	.19
Total	100.11

This is much more like the analysis of a granitite than the last one given (No. 11082), but the preponderance of soda over potash indicates the presence of a large amount of soda orthoclase.

Schistose Porphyries or Porphyroids.—Just below Upper Quinnesec Falls, especially on the Wisconsin side, are good exposures of finely schistose acid rocks. They contain small porphyritic crystals of feldspar and quartz, and a considerable amount of sericite or hydro-mica, which winds around these crystals so as to produce a lenticular or "Flaser" structure. In color they present every shade from flesh red to gray.

Rocks of this general type have a wide distribution and have arrested the particular attention of petrographical investigators. In some instances they have been conclusively shown to be the product of the metamorphism of fragmental rocks—either tuffs or true sediments—while in other cases they have resulted from the action of great dynamic forces upon massive rocks of a corresponding composition, i. e. quartz porphyries. When it is possible to trace with certainty the origin of these rocks to stratified deposits they are usually designated as *porphyroids*, while in case their mother-rock can be shown to have been quartz porphyry they are usually called *schistose porphyries*. In their extreme development these two types are often petrographically indistinguishable and they present an instructive instance of the production of identical results by the action of the same physical forces upon matter of the same average composition, though differing widely in origin and its structure.[1]

The schistose porphyries occurring at Upper Quinnesec Falls were made the subject of an extended paper by Hermann Credner, published in 1870.[2] This author concludes from a macroscopical examination that these rocks are altered sediments which are interpolated between the

[1] Bull. U. S. Geol. Survey, No. 28, p. 1.

[2] Ueber Nordamerikanische Schieferporphyroide. Neues Jahrbuch für Mineral., 1870, pp. 970-984.

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diabase beds of the Upper Huronian. He divides their whole exposure at this locality, which he gives as 300 feet, as follows:

	Feet.
(b) Weakly schistose orthoclase porphyroid	50
(c) Typical feldspar-paragonite schist	10
(d) Light flesh-red orthoclase-paragonite schist	30
(e) Paragonite schist	15
(f) Lime-paragonite schist	15
(g) Light reddish gray schistose porphyroid	30
(h) Lime-chlorite schist	50
(i) Chlorite schist	100
Total	300

Of (b), (c), (d), and (e) he gives the following analyses:

	(b)	(c)	(d)	(e)
SiO_2	66.70	72.45	76.505	75.5
Al_2O_3	15.90	8.85	7.950	8.6
Fe_2O_3	4.70	6.20	8.875	2.6
MnO	tr.	tr.	tr.	.....
CaO	tr.	tr.	0.322	7.2
MgO	.....	.....	tr.	1.2
K_2O	8.06	9.24	1.025	0.3
Na_2O	5.50	3.70	4.384	3.0
H_2O	.....	.....	.....	1.5
Total	100.86	100.44	99.061	99.9

In discussing these analyses Credner finds sufficient proof that orthoclase alone is present, from the fact that the potash increases proportionately with the amount of feldspar, and in the absence of a twinning striation which is visible to the naked eye. The sodium he attributes entirely to the mica, which, in consequence, he names paragonite. The proof of sedimentary origin he finds in the constant parallelism of the schist planes with the limit between these rocks and the adjoining diabase; and yet he cannot help being much struck with the alternation of such widely diverse rocks in a single and comparatively thin complex.[1]

My studies of these rocks, both in the field and in the laboratory, have led me to results quite the reverse of those obtained by Credner. Nos. 11050 to 11053 were collected from the most typical band, which here stands nearly vertical and strikes 20° S. of E. They are all essentially the same in everything except color. They contain more or less rounded porphyritic crystals of quartz and a red or grayish feldspar, imbedded in a matrix apparently composed of a yellowish gray, greasy-feeling hydro-mica.

[1] Die ebenerwähnte Wechsellagerung vollkommen verschiedenartiger Gesteine als zusammengehörige Glieder einer wenig mächtigen Schichtenreihe ist höchst auffällig. Zwischen zwei Lagern von Diabas, also einem namentlich aus Kalkfeldspath und Augit bestehenden basischen Gesteine mit etwa 54 Proc. Kieselsäure tritt zunächst eine Zone von sauren quarzreichen Kalifeldspath-Natronglimmer-Porphyroiden mit über 70 Proc. Kieselsäure, aber ohne Kalkgehalt auf," etc.—Loc. cit., p. 981.

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The following analysis of No. 11050 by Mr. R. B. Riggs shows its essential identity with Credner's specimen (b). Almost the only difference is the smaller amount of alkali, although the relative proportions remain about the same. In Credner's analysis the CaO and MgO, which make up this difference, do not appear to have been determined.

Silica (SiO_2)	66.69
Alumina (Al_2O_3)	16.69
Ferric oxide (Fe_2O_3)	2.06
Ferrous oxide (FeO)	.93
Lime (CaO)	1.40
Magnesia (MgO)	1.15
Soda (Na_2O)	2.46
Potash (K_2O)	5.23
Water (H_2O)	1.70
Carbon dioxide (CO_2)	1.42
Total	99.73

This is evidently the analysis of an orthoclase rock, and yet the microscope shows that a considerable proportion of the porphyritic feldspars are striated and triclinic, in spite of the fact observed by Credner, that this character is not apparent to the unaided eye. We may therefore reasonably suppose that the potash exists largely in the groundmass and in the secondary hydro-mica, which is to be regarded as true sericite, and not paragonite as assumed by Credner.

The microscope discloses in all the thin sections of these rocks the typical structure of a quartz porphyry modified, however, by the action of great pressure. An idea of it may be obtained from Pl. XIV, fig. 1, which represents No. 11050. The fine grained, micrograniticc groundmass is still present, inclosing the porphyritic quartzes and feldspars. The former often exhibit their characteristic dihexahedral form, but they are broken and possess an undulatory extinction. The feldspars are most instructive. They possess a sharply defined crystal form which, however, has been cracked and the fragments have been more or less separated in the direction of the schistosity, while brightly polarizing sericite scales have been abundantly developed in all the fissures. Sericite is also abundant in the groundmass, where it appears to have been formed from the orthoclase. Its scales are parallel throughout the rock, to which fact the schistose structure is almost wholly due. The original biotite of these rocks is now entirely represented by a pale green chlorite. During the process of this alteration, iron has separated in the form of opaque, black grains; and, in some instances (11050 and 11052), colorless but very highly refractive grains have been produced. These sometimes possess a sharp octahedral form and are probably anatase, formed from the titanic acid of the original biotite, as described by Stelzner.[1] In and around this chlorite, tourmaline is also abundant either in single individuals or in groups of crystals. Zircon and apatite are sparingly present. One

[1] Neues Jahrbuch für Mineral., 1884., vol. 1, p. 273.

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remarkably large (.4 × .04^{mm}) crystal of the former mineral, which has been curiously broken, is represented in Fig. 18, taken from No. 11052. Calcite is not uncommon and is always of a secondary nature. In Nos. 11051 and 11053 it forms a more or less complete border around the porphyritic crystals.

FIG. 18.—Broken zircon crystal in schistose porphyry. Upper Quinnesec Falls. No. 11052. Magnified 180 diameters.

As already stated, all four specimens collected from this locality are essentially identical. No. 11053 is more finely schistose, owing to its more advanced stage of alteration and the consequent greater production of sericite. In spite of this, however, the original structure is still plainly visible. No. 11096 was obtained on the Michigan side of the river, at the foot of the Horse Race. It has a very pronounced schistose structure, and, under the microscope, appears nearly identical with the rocks just described from below the falls, but is not so highly altered. Its biotite is in its original fresh state, its porphyritic crystals are more intact, and sericite is not so abundantly developed.

Gneiss.—In addition to the nonporphyritic gneisses already described, Nos. 11079, 11084, and 11085 (see pp. 114–115) one other may be mentioned, No. 11188, from the head of the Horse Race, on the Michigan side. This is apparently a typical biotite gneiss, but it is seen to pass by gradual transitions into the hornblende gneiss No. 11189 (see p. 108). The microscope shows that there are many points of resemblance between these two rocks. In the present case, although quartz is abundant, amphibole and the same sphene observed in No. 11189 are frequent, and the feldspar is of such a nature as to be subject to saussuritization.

Felsite.—True nonporphyritic felsite is not common among the acid rocks of the area about the Upper Quinnesec Fall and the Horse Race. The most typical specimen of this class is No. 11071, which occurs in narrow bands in the schistose greenstones below the falls on the Michigan side of the river. This is a very compact, flesh colored rock resembling jasper. Under the microscope it is seen to be essentially identical with the groundmass of the porphyritic rocks above described; and even here stretched and distorted crystals of quartz and feldspar are not entirely wanting, though they are rare.

There is, therefore, strong evidence in favor of the view that the acid rocks of the Upper Quinnesec region are of eruptive origin; that they are to be regarded as apophyses which diverged from the granitic mass to the south; and that their schistose structure, when present, is to be attributed to secondary causes.

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This evidence may be summarized as follows:

First. The structure of these rocks, as revealed by the microscope, in spite of its frequently being disguised by the action of secondary causes, is always that recognized as characteristic of massive or igneous rocks.

Second. There are present in these gneissoid bands granitic facies which agree exactly with the rock of the main granite area, and the bands themselves are identical with others near the contact, which can be plainly seen to be radiating apophyses or dikes.

Third. The schistosity of these bands is often independent of their direction and agrees with the prevailing strike of the surrounding greenstones.

Fourth. There is abundant microscopic evidence that the constituents have been fractured, stretched, and crushed since their solidification.

The localities thus far considered on the Menominee River, viz: Sturgeon, Lower and Upper Quinnesec Falls, contain all the important exposures of crystalline rocks, belonging to what Major Brooks has regarded as the southern of the two belts of greenstone. If his location of these rocks is correct, the members of the northern belt appear upon the river at three points, viz: Four-foot Falls, Lower Twin, and Upper Twin Falls, of which, however, the two latter are connected by almost continuous rock exposures. These localities we shall now proceed to consider in detail.

FOUR-FOOT FALLS.

The exposures at this place are represented, together with those at both the Twin Falls, upon Major Brooks's map, which is here reproduced in Pl. VI. The fall is hardly entitled to be so called, as the rocks have formed nothing more than a rapid in the river. Just at the foot of this rapid the river is crossed by the Chicago and Northwestern Railroad bridge, immediately beyond which a cutting has disclosed some very instructive exposures of the greenstones. The rocks may be seen in position on either side of the river for some distance above the bridge. Brooks distinguishes upon his map many alternating beds of massive, schistose, and slaty rocks (*a* to *n* in his section). The beds here strike about S 80° E—nearly at right angles to the direction of the river at this point—and yet are mostly schistose on the Wisconsin side and massive on the Michigan side. This fact is indicated on Major Brooks's map and speaks strongly against the view that the present foliation is due to original bedding.

The rock of the exposure which occurs farthest down the river (Brooks's *a*) outcrops somewhat less than a quarter of a mile below the bridge. It was called by Wright a chloritic slate,[1] and by Wich-

[1] Geol. Wisconsin, vol. 3, p. 712.

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mann a phyllite. Major Brooks himself designates it as a "light bluish gray, shining *clay slate*, with strong cleavage and no distinguishable bedding planes."[1] It does not belong to the rocks now especially under consideration, but since it was studied carefully it may be described here for comparison. This slate occurs in a bed, estimated by Brooks to be 550 feet in thickness, on both sides of the river and in its bed. It strikes nearly east and west and dips toward the north. In Brooks's collection this rock bore the number 2075; in the present collection it is represented by No. 11152.

Under the microscope there are visible in the thin section of this specimen unmistakable signs of sedimentary origin. Coarser and finer areas alternate, the former being made up of clastic quartz grains, either pure or mixed with iron hydroxide or chlorite, while the latter are composed of an argillaceous substance, filled with extremely minute muscovite or sericite scales and considerable carbonaceous matter. Tourmaline needles are also occasionally seen; and zircon too, either in minute, whole crystals or as irregular fragments of larger ones, is not infrequent. This rock belongs to the detrital iron-bearing series, the boundary between which and the greenstone schists lies just above this exposure.

The railroad which crosses the bridge at Four-foot Falls exposes this same rock again in a cutting about a mile west of Iron Mountain. A specimen from this locality, No. 11114, shows the same general character as the last described rock, except that it is more crystalline. Tourmaline is present as before, but a new crystallization of biotite has largely replaced the chlorite. The carbonaceous material is less abundant and what remains is in a much more finely divided state. The clastic origin of the rock is still very apparent in the shape of its quartz grains, which are here mingled with feldspar fragments, both plagioclase, microcline and orthoclase.

No. 11113, from a quartzite band intercalated in No. 11114, also contains feldspar grains mingled with the quartz. Zircon fragments are likewise present and a little biotite, which is no longer quite fresh. This latter mineral shows in a beautiful manner the development of secondary rutile needles, as in the kersantites.[2]

Before speaking of the greenstones which occur along the river farther north, it will be well to examine those exposed in the railroad cutting at the western end of the bridge. These rocks are, for the most part, massive, but they nevertheless display evidence of extensive crushing and chemical alteration. No. 11178 represents the average type. This is of a light green color, and in a hand-specimen quite aphanitic. Both macroscopically and microscopically it resembles the massive greenstones so abundant in and representative of the region south of Marquette (see Pl. X, fig. 2). Mineralogically there is hardly a trace of the original rock left. Almost colorless hornblende, pale

[1] Geol. Wisconsin, vol. 3, p. 475.
[2] Rosenbusch: Mikros. Physiog., 2d ed., vol. 2, p. 311.

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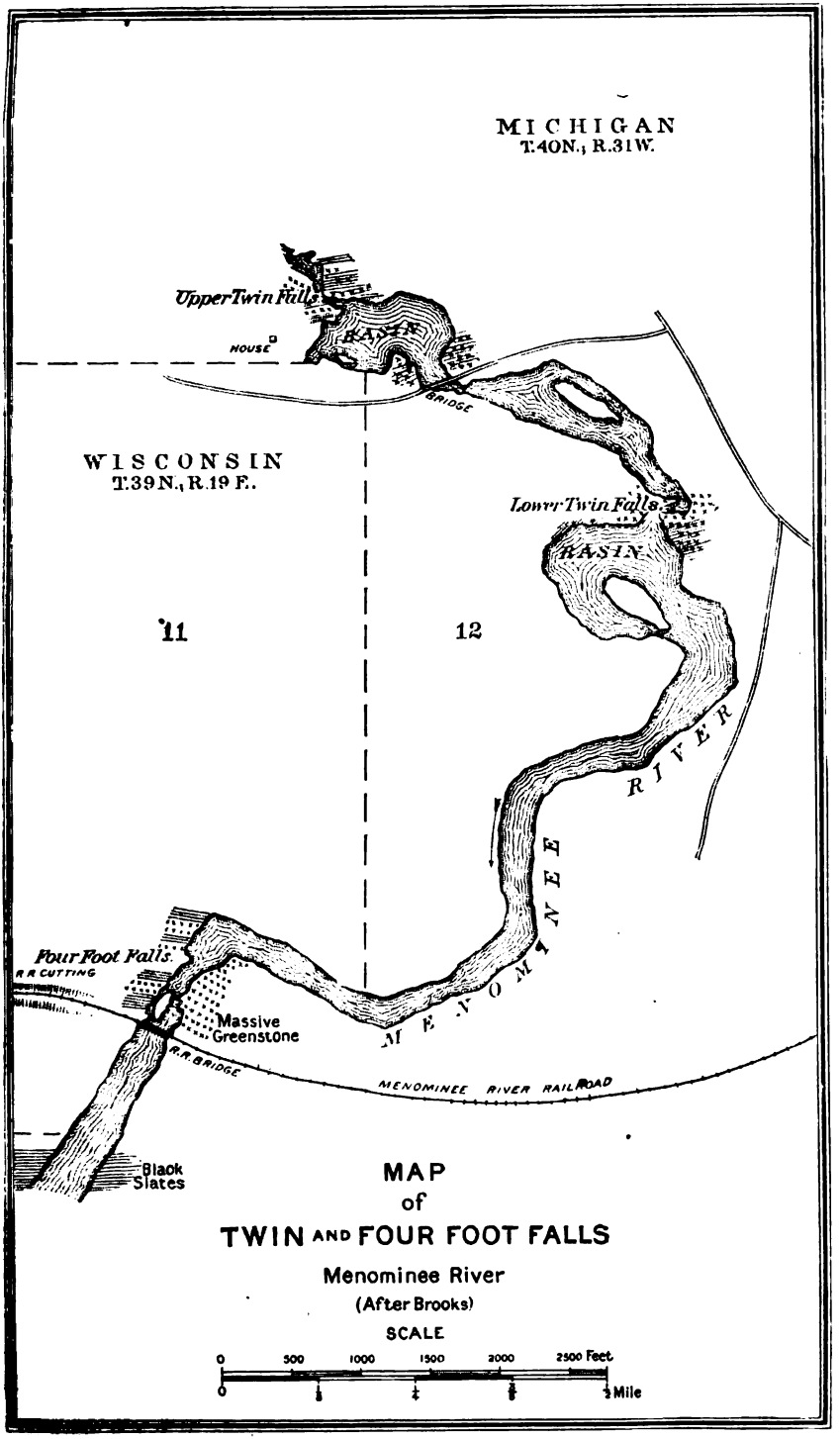

MAP
of
TWIN AND FOUR FOOT FALLS
Menominee River
(After Brooks)
SCALE

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green chlorite, zoisite, leucoxene and a little calcite (all of secondary origin) are the present constituents; and yet the original structure of the rock is strikingly well preserved. When viewed with a comparatively low power, in ordinary light, the outlines of long, almost acicular, feldspar crystals are very apparent, in spite of the fact that the substance of the feldspar itself is changed to chlorite or zoisite. These outlines of former crystals make a confused aggregate, but each individual preserves its own proper form (idiomorphic in the sense of Rosenbusch). The angular spaces between the feldspars produce a typical example of the ophitic or diabase structure, although no trace of a diabase mineral remains.

But the exposure is not throughout as massive as the specimen just described. It is traversed here and there by schistose and wavy bands which show indications of having been much crushed and rubbed. Slickensides are abundant and lenticular fragments fit into one another so as to produce an imperfect sort of foliation. In other cases, where the crushing has been more intense, the schistosity is more perfect. These bands all strike a few degrees north of west, being apparently conformable to the slates below and the greenstone schists above. This is a suggestive fact when it is remembered, as observed by Brooks, that these slates owe their lamination to slaty cleavage (a product of pressure), which seems to have obliterated the original stratification.

No. 11179, from one of the schistose bands in the greenstone of this cut, shows under the microscope the effects of great mechanical action. Curving and interlacing areas of pale green chlorite and of a grayish substance (perhaps the remains of titanic iron) form the main mass of this rock. Thickly scattered through these are patches of a dark brown substance, often showing concentric zones of a clear, transparent character. These look like opal, but their optical character shows them to be single individuals of crystalline quartz. Imbedded in this material of such pronounced secondary character, are fragments of feldspar, which have been crushed or broken. These, as has been observed so frequently before, are less changed chemically than those in the massive rock from which this schistose band has been derived.

Four specimens were selected to represent the series collected along the river north of the railroad bridge. Two of these came from each side of the river and illustrate both the massive and schistose bands.

No. 11176 was found on the Michigan (eastern) side, just above the bridge. In color it is light green, and in structure it is massive. Under the microscope it shows a pale hornblende in ragged and irregular individuals, feldspar, zoisite, chlorite, and leucoxene. Traces of an original diabase structure are still abundant in this rock. The feldspars often perfectly preserve their lath-like form and their twinning striation, while the pale but compact hornblende occupies the intervening spaces, supplying the place taken by the augite in fresh rocks of this type.

No. 11175, from the highest exposure on the Michigan side of Four-

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foot Falls, is quite schistose and of a much darker color than the last rock. Under the microscope it is seen to possess a much finer grain and to be composed of hornblende, chlorite, feldspar, quartz, and leucoxene. The hornblende is for the most part pale green, but that it was bleached from the brown variety is shown by the numerous compact brown cores which occur in the centers of the paler crystals. The structure of this rock is purely granular, with no trace of the diabase type which characterized the specimen last described. This fact and the indication that the pale, fibrous hornblende was derived from a compact, brown variety of the same mineral, render it probable that this rock was originally a diorite, composed of feldspar and brown hornblende, in which little or no pyroxene was ever present. The hornblende of this rock exhibits a structure quite similar to that described by Becke[1] and Van Hise[2] as due to a secondary enlargement of the crystals in a solid rock.

The accompanying figure represents the compact brown interior of a hornblende individual, more or less sharply separated from a pale green or colorless border of hornblende fibers, which possesses exactly the same optical orientation as the core.

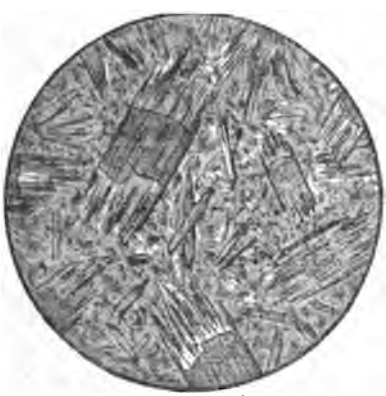

FIG. 19.—Compact cores of hornblende surrounded by a fibrous border, No. 11175, a schistose greenstone from Four-foot Falls. Magnified 180 diameters.

Evidence seems to be constantly accumulating that various minerals may continue their growth by regular accretions in solid rocks, whether massive or clastic. This fact is satisfactorily established at least for quartz, feldspar[3] and hornblende. While not in the least doubting the correctness of the conclusions above cited in regard to the secondary growth of hornblende, I must, however, confess that the present isolated instance appears to me hardly to offer conclusive proof that the fibrous hornblende border is a secondary crystalline enlargement. Such an explanation is possible, but the appearance can be equally well explained in my judgment, by assuming that the fibrous zone is the result of bleaching and fraying out of originally compact hornblende crystals. This process would naturally commence at the ends of the crystals and develop principally in the direction of the cleavage, as is here seen to be the case. The only difficulty with this explanation is the sharp line sometimes seen between the brown and the fibrous hornblende. But such a sharp boundary is rather the exception than the rule.

[1] Tschermak's mineral. u. petrog. Mittheil., vol. 5, 1883, pp. 158-59. (cf. Am. Jour. Sci., 3d series, vol. 33, p. 385, 1887.)

[2] Am. Jour. Sci. 3d series, vol. 30, p. 231, Sept. 1885. A. Harker has also recently described similar secondary enlargements of hornblende in a hornblende-picrite from Anglesey. Geol. Mag., London, 3d series, vol. 4, 1887, p. 550.

[3] See Irving and Van Hise: Bull. U. S. Geol. Survey, No. 8.

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Nos. 11142 and 11143, taken from two contiguous bands on the Wisconsin side of the river, about midway between the two points which furnished the last described specimens, represent Brooks's localities *l* and *k* respectively. The first is schistose, the second massive. The first is a pale and schistose aggregate of nearly colorless chlorite, light green or colorless hornblende fibers, quartz and calcite. The second is a much darker green mixture of feldspar, hornblende, chlorite and leucoxene. The first named of these components has frequently its crystal form well preserved, which betrays the diabase character of the mother rock. The leucoxene in this section, as well also as in Nos. 11175 and 11176, often possesses the sphene-like habit which has been figured from No. 11189. (Pl. XIII, fig. 1.)

THE TWIN FALLS.

About a mile above the last described rock exposure at the so-called Four-foot Fall, the quiet course of the Menominee River is again interrupted by a very considerable outcrop of greenstone. This is almost continuous for half a mile, but at either end of it the river plunges over a barrier of somewhat harder rock than usual and spreads out below it into a small basin. The two little water-falls thus formed are known as the Twin Falls. In Major Brooks's report they are included in the same map that shows the topography of the Four-foot Fall,[1] and that portion of this map which gives the outline of the Twin Falls is reproduced in twice the scale of the original on Pl. VI.

All of these exposures belong to the northernmost of the two greenstone belts of the Menominee Iron Basin. This is much more uniform in its composition than the southern belt, in which the Sturgeon and Quinnesec Falls exposures are located. Its rocks are altogether of a dark green, almost aphanitic type, which, when they become schistose, give rise to dark chloritic slates. Neither the light colored, gabbro-like greenstone, nor coarse diorites, like those of the Horse Race, nor bands of acid rocks occur in the northern belt—at least, not at the localities where this crosses the river.

The homogeneous character of the Twin Falls greenstones is largely due to an advanced state of chemical alteration, which has obscured its original grain.

The macrostructural changes, whereby the compact, dark green rocks are converted from a massive to a schistose state, may be admirably seen along the river banks at both the Upper and the Lower Twin Falls. The foliation of the massive and already chemically altered rock takes place in a somewhat different manner from that heretofore described. There are none of the ragged "cross gashes" and irregular, gaping seams (see Fig. 10, p. 81) which are so common at the exposures along the southern belt. These seem to be the result of stretching in a solid or very nearly solid mass, but in the present case this process is hardly apparent.

[1] Geol. Wisconsin, vol. 3, p. 475, Pl. IV.

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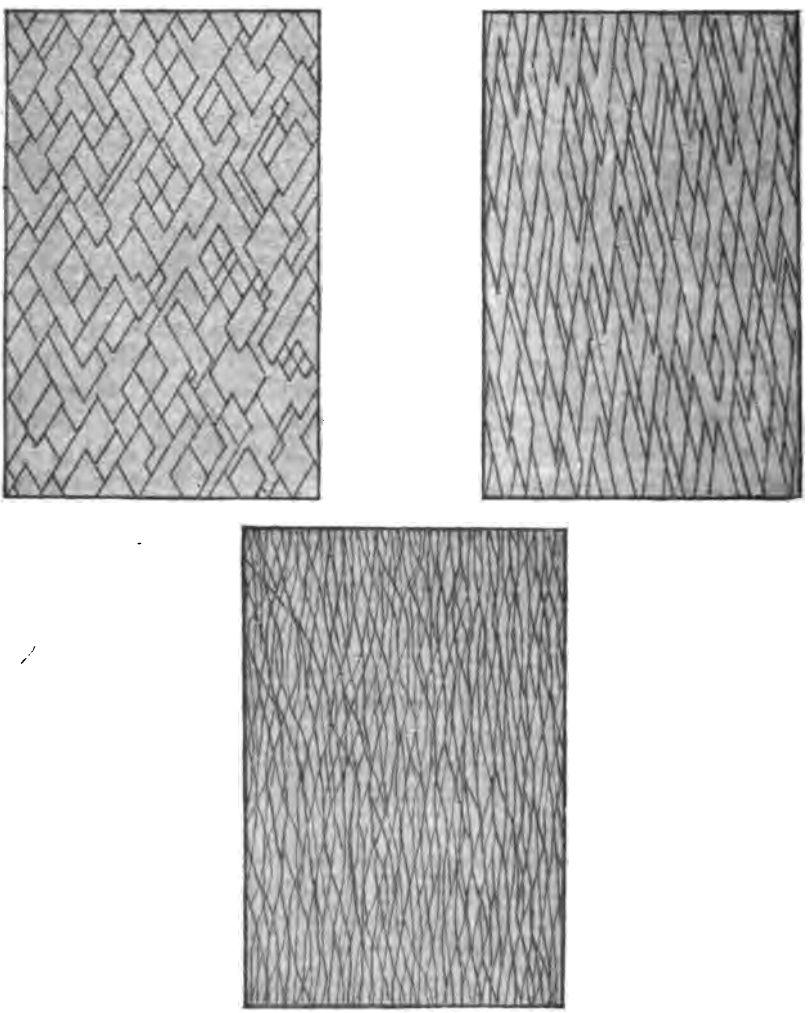
The first step toward the formation of a schistose structure in these Twin Falls greenstones (and this is hardly ever absent) is the division of the massive rock by two systems of joints, which stand about perpendicular to the surface and intersect at a varying but acute angle. These joint systems divide the mass into diamond shaped or rhomboidal prisms, the cross sections of which are well displayed upon the frequent smoothly glaciated surfaces of the rock. The appearance of such a surface is diagrammatically represented in Fig. 20.



FIGS. 20-22 diagrams illustrating the transition from jointing to schistose structures in the greenstones at Twin Falls.

As we approach the schistose band in the massive rock these interlacing rhombs become lengthened out more and more by an approximation to parallelism between the two systems of joint-planes. (Fig. 21.)

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These elongated prisms finally become very much extended lenses, which interlock and produce a well developed, wavy or even parallel schistose structure (Fig. 22). The almost slaty rocks thus produced, especially as seen at Lower Twin Falls, have a tendency to break, not so much along a definite plane as parallel to a line—i. e., the direction, normal to the surface, parallel to which the original joint planes ran. It is difficult to obtain well shaped hand-specimens of these rocks, but narrow rhombic prisms of almost any angle are easily procured. There is an almost equal tendency to cleave along any plane which is parallel to the longest axis of these prisms.

If the prisms due to the original joint planes were subjected to a lateral pressure which developed in them a cleavage that successively approached more and more nearly to the long axis as the prism was lengthened, this peculiar tendency to separate along a line rather than along a plane is precisely the structure which we might suppose would result.

The strike of these schistose bands follows the direction which bisects the acute angle of the rhombic prisms. This is for the most part from S. 70° to 80° E., agreeing with the prevailing strike of all the rocks in this system. There are, however, many exceptions, where these schistose bands, even where near together, follow different directions; for instance, I observed, in the massive though jointed rock on the Michigan side of Upper Twin Falls, two schistose chloritic bands quite near together, one having a strike N. 180° E., and the other S. 73° E., while the dip of each was nearly vertical. Such cases are easily explicable on the supposition that these bands were produced by mechanical agencies, but it is quite impossible to reconcile them with the supposition that these bands are in any way the result of sedimentation.

This type of schistose structure was also noticed to a slight extent at some of the exposures of the lower greenstone belt—notably just below Lower Quinnesec Falls on the Michigan (left) bank of the river (see p. 84). It is, however, there the exception, and is peculiarly the characteristic of the upper belt as exhibited at the Twin Falls.

LOWER TWIN FALLS.

The development of the foliation in the massive greenstone is also shown on a small scale, particularly on the left (Michigan) side of Lower Twin Falls, where there has been a slight amount of slipping along a line of jointing. Fig. 23 gives a diagrammatic idea of a specimen observed at this locality. The area represented is about three feet square. Through the center runs a vein of white quartz which has been depos-

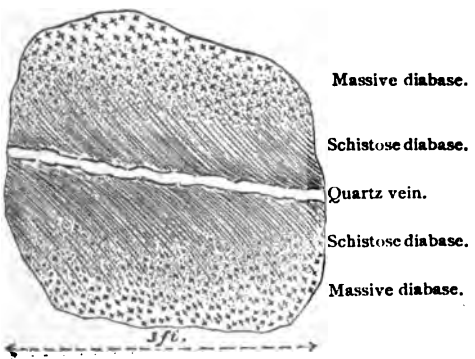

FIG. 23.

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ited by infiltration in the old joint seam. On the edges of this the rock is perfectly schistose and chloritic, but it passes gradually, in the space of a few inches, into the massive aphanitic greenstone, which composes almost all of this exposure. Fig. 24 represents a polygonal block, formed by the jointing of the massive greenstone, which has been frayed out into a perfectly foliated chlorite schist by a slipping movement against the adjoining blocks.

The extensive chemical alteration which has gone on in this greenstone seems to render it peculiarly subject to such a fraying out into a chloritic schist. This change takes place in cases where a fresher and harder mass would have received only a slickensides.

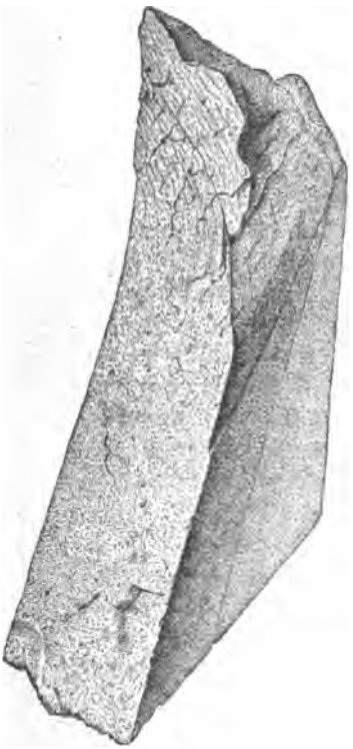

FIG. 24.

The Twin Falls greenstones are interesting, in view of the macrostructural alterations which they exhibit. Mineralogically they are all so much decomposed that they present but little which is determinable under the microscope.

The least altered specimen collected is No. 11140, from the east side of the Lower Fall. Together with the specimens shown in Figs. 23 and 24, it came from a steep wall of massive and but little jointed greenstone, which rises abruptly from the water's edge. Diamond jointed and somewhat schistose rocks of the same sort occur on the north (No. 11139) and fissile chloritic slates (striking W. of N. and dipping 70° to the north) to the south of it. Under the microscope this massive rock is found to be a confused aggregate of pale green, somewhat fibrous hornblende, feldspar remnants, and leucoxene, which possesses a sphene-like habit and rarely shows any trace of its original ilmenite. The clearer areas, which represent the former feldspar, are now so filled with actinolite, zoisite, and epidote needles, that nothing regarding the former character of this mineral can be learned. In this rock secondary biotite is also quite abundantly developed, as was found so often to be the case in the Russian metamorphosed diorites described by Inostranzeff[1]. The original structure of this rock is now disguised almost beyond recognition, but it seems to have partaken more of the granular nature of a diorite than of the ophitic nature of a diabase.

No. 11132, taken from the continuation of this mass on the opposite

[1] Studien über metam. Gest., etc., 1879, pp. 81, 82, 109-112.

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side of the river, is essentially identical with it, but in it the form of the original feldspars is better preserved. These may often be seen in well formed, lath-shaped crystals, which, in spite of their extensive saussuritization, still retain distinct traces of their plagioclastic twinning striæ. This rock also, in distinction from the one last described, contains some chlorite but no biotite.

These rocks, like so many others of the Menominee River greenstones, are representative examples of the type called by Gümbel "Epidiorit," which is now generally conceded to be an altered form of diabase.[1]

The rocks into which these least altered forms pass are representative chlorite schists and slates; and there can be no doubt that these latter have also resulted from the extreme effects of those metamorphic agencies which changed the eruptive diabase to the epidiorite.

No. 11130, collected just below No. 11132, and grading imperceptibly into it, is a schistose rock, composed of bright green chlorite, finely granular quartz and, perhaps, secondary albite. The leucoxene in this rock is particularly interesting. It still retains small ilmenite cores in places, but it is broken and pulled out in the direction of the schistosity. A very considerable portion of this leucoxene, especially around the edge of the grains, is composed of highly refractive and brightly polarizing, although extremely minute, colorless crystals. These have an octahedral habit and resemble anatase (Fig. 25), which, as both Diller[2] and Rosenbusch[3] have shown, sometimes originates from the alteration of ilmenite (cf. also Nos. 11050 and 11052 p. 121). Biotite also occurs in small quantities in this rock.

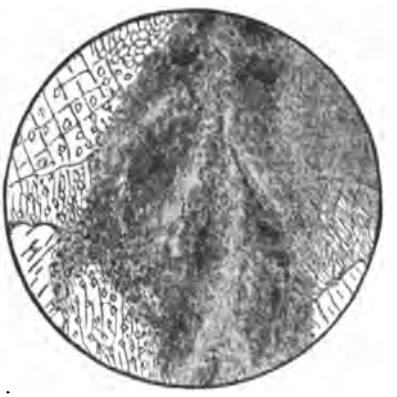

FIG. 25.—Anatase derived from ilmenite, No. 11130, from the Lower Twin Fall. Magnified 180 diameters.

At the northwestern corner of the basin, below the Lower Twin Fall (see map Pl. VI), the rock is rhomboidally parted and weathers to a brownish color. In spite of its massive appearance it possesses a latent tendency to cleave along the longest diagonal of the rhomboidal prisms, and this tendency is intensified by weathering. Toward the east this rock (No. 11128) passes gradually into corresponding slates (No. 11129). Under the microscope these two rocks are seen to be in all respects the equivalents of Nos. 11132 and 11130, above described. Their main difference consists in their being richer in iron, which has oxidized and

[1] Cf. Rosenbusch: Mikros. Physiog., 2d ed., vol. 2, p. 205.
[2] Neues Jahrbuch für Mineral., 1883, vol. 1, p. 191.
[3] Mikros. Physiog., 1st ed., vol. 2, 1877, p. 336; 2d ed., vol. 1, 1885, p. 332, cf. also Schenck; Inaugural Dissertation, Bonn., 1884, p. 25.

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stained the rocks brown. No. 11128 still retains much hornblende, feldspar, and ilmenite, and the diabase structure is still apparent in places. No. 11129 is, like its counterpart No. 11130, a chlorite schist with the hornblende replaced by chlorite, the feldspar by a quartz albite mosaic, its leucoxene drawn out, and its structure wholly changed.

Perhaps the most altered rock of any encountered at the Lower Twin Fall is No. 11139, which was one of the chloritic slates on the Michigan side of the river below the massive rocks. This is a very fine grained aggregate of pale green chlorite, quartz, or quartz albite mosaic and biotite, the latter constituent being sparingly present. Sharply defined crystals of tourmaline are also abundant in this rock.

UPPER TWIN FALLS.

At the Upper Twin Fall the same massive greenstones with a rhomboidal parting prevail, everywhere traversed by more or less schistose bands. No. 11133 is the massive rock from the left or Michigan side of the fall. It is much altered chemically, but preserves its original structure almost perfectly. When examined by a low magnifying power there is seen a network of light colored, lath shaped feldspar forms, which are almost acicular, like those of a porphyrite. Between these is an allotriomorphic mass of a dark gray substance, representing the former augite, or possibly a glassy base. When examined more carefully with a higher power, the feldspar is found to be completely replaced by a mixture of pale green chlorite and brown biotite in the closest relationship, while in them an occasional crystal of zoisite is imbedded. The darker interstitial mass is composed largely of fibrous hornblende in shreds or confused, matted masses, but these are mingled with much impure and indeterminable matter.

Two schistose bands have already been mentioned on p. 129 as traversing this rock in different directions. Of these, the one striking S. 73° E. is the less schistose, and is represented by specimen No. 11135. Though much more altered than the last, there are here also occasional unmistakable traces of the same ophitic structure. The representative of the other band, No. 11134, is hardly more than a fine schistose aggregate of chlorite, quartz, and calcite, with only the faintest indications of its original structure, and yet here there are beautiful leucoxene borders around unaltered cores of ilmenite. Narrow veins filled with a mixture of calcite and chlorite traverse all these rocks.

On the opposite or Wisconsin side of the Upper Twin Falls the rocks are apparently the same, but they show, nevertheless, important microscopic differences. The massive forms represented by Nos. 11122, 11125, and 11126, collected at different points between the falls and the bridge, are fine and confused aggregates of pale green, fibrous hornblende, chlorite, zoisite, quartz, leucoxene, and occasionally (No. 11122) a little biotite. All of these minerals are of secondary origin and in

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the process of their formation most of the traces of the former rock-structure have been obliterated. Such traces as still remain indicate that the mother-rock was a diabase, but there are seen none of the long, acicular feldspar forms, discovered in the rocks from the opposite side of the river.

The schistose bands interlaminated with these rocks are quite like those already described. One of these, however, No. 11123, obtained directly beside the falls, shows almost the only evidence of fragmental origin anywhere observed in the Menominee greenstones. This contains irregular and angular fragments of quartz and a slightly altered feldspar of considerable size. These are imbedded in a matrix of irregular grain, composed of chlorite, calcite, quartz, and opaque iron oxide, which is accompanied by leucoxene. The chlorite scales often have a radially divergent arrangement around the larger included fragments of quartz and feldspar.

Thin section, No. 11122, shows the contact of this schist with the massive rock. This contact is so sharp as to lend much additional probability to the idea that in this case the two rocks are of different origin.

Rocks of this kind are to be regarded as diabase-tuffs, similar to those which are so largely developed around Marquette, and which are to be described in the sequel. It is easy to see how essentially the same material, whether produced as volcanic ash or as a massive rock, when subjected for a long period to the action of the same metamorphosing forces, would give rise to masses which, in certain cases, could not be distinguished from one another. This is undoubtedly true of many occurrences on the Menominee River, and hence we can speak with certainty only of those instances where sufficient of the original structure is preserved to do away with all doubt. Between undoubted massive rocks rendered schistose by pressure on the one hand, and fragmental tuffs which have been more or less completely solidified by the same agency on the other, there must therefore be rocks whose original form must always be uncertain.

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CHAPTER IV.

GREENSTONE BELTS OF THE MARQUETTE DISTRICT.

INTRODUCTORY.

Ever since the discovery of iron in the northern peninsula of Michigan, in 1844, by Burt and Houghton, the region around Marquette has received much attention from geologists. Although not so early known as the famous copper district of Keweenaw Point, this iron region has divided the scientific interest which was before felt in the copper-bearing rocks.

Douglass Houghton,[1] Locke,[2] Foster and Whitney,[3] Whittlesey,[4] Kimball,[5] Credner,[6] Brooks,[7] Wright,[8] Wadsworth,[9] Rominger,[10] and Irving[11] have studied the general relations of the deposits, while microscopical descriptions of some of the rocks have been given by Julien,[12] Wright,[13] Wichmann,[14] Pumpelly,[15] Wadsworth,[16] and Irving.[17]

The city of Marquette is situated on the south shore of Lake Superior, about midway between the Carp River and the promontory known as Presqu' Isle, between which points (a distance of about 4 miles) the lake shore runs nearly north and south. The city for the most part lies within the square mile designated as Sec. 23, T. 48 N., R. 25 W., Michigan.

An excellent idea of the topography of this region and of that extending for 18 miles back of it (i. e., westward from the lake) may be obtained from the large colored map prepared by Dr. C. Rominger.[18]

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[1] Brooks, Geol. Michigan, vol. 1, 1873, p. 13.

[2] Geol. Michigan, vol. 2, 1873, p. 239.

[3] Senate Docs., 1st session, 30th Congress, 1847-'48, II, Doc. 2. Report on the Geology and Topography of the Lake Superior Land Dist., Part II, Iron Region.

[4] Proc. Am. Assoc. Adv. Sci., 1859, vol. xiii, part 2, pp. 301-308; ibid., 1875, vol. 24, part 2, pp. 60-72.

[5] Am. Jour. Sci., 2d series, vol. xxxix, 1865, pp. 290-303.

[6] Zeitschr. Deutsch. geol. Gesell, vol. xxi, 1869, pp. 516-554.

[7] Geol. Michigan, vol. 1, 1873, part 1. pp. 1-319.

[8] "Geology of the Lake Superior Iron District" in Swineford's History and Review of the Copper, Iron, Silver, Slate, and other Material Interests of the South Shore of Lake Superior, 1876, pp. 132-145.

[9] Bull. Mus. Comp. Zool., Cambridge, vol. 7, No. 1.

[10] Geol. Michigan, vol. 4, part x, Marquette Iron Region, 1881, pp. 1-154.

[11] Preliminary paper on an Investigation of the Archean Rocks of the Northwest; Fifth Ann. Rep. U. S. Geol. Survey, 1886, pp. 181-242.

[12] Geol. Michigan, vol. 2, 1873, Appendix A.

[13] Geol. Michigan, vol. 2, 1873, Appendix C.

[14] "Microscopical Observations of the Iron-bearing (Huronian) Rocks from the region south of Lake Superior," 1876, Geol. Wisconsin, vol. 3, pp. 600-656.

[15] Am. Jour. Sci., 3d series, vol. x, 1875, pp. 17-21.

[16] Bull. Mus. Comp. Zool., vol. 7, No. 1.

[17] Bull. U. S. Geol. Survey No. 8, pp. 27-30.

[18] Geol. Michigan, vol. 4, 1881, in pocket.

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The general trend of both the drainage and of the geological formations within this area is toward the east. The two main streams follow somewhat irregular but approximately parallel (eastward) courses and empty into the lake about four miles apart. The more northerly of these is called the Dead River; the more southerly the Carp.

The general surface of this area rises by degrees from the level of the lake to an elevation of about 1,000 feet above the lake. This surface is, however, extremely broken and hilly, being traversed by east and west ridges composed of rows of rocky knobs. These elevations are never over two hundred feet in height from the base; usually they are much lower (from one hundred to fifty feet or even less). They all have rounded outlines produced by the wearing action of the great glacier, evidences of which are everywhere apparent in the smoothly polished and frequently striated rock surfaces. These knolls rise from the even level of a plain produced by the glacial débris deposited between them.

An account of the general geological structure of the Marquette region has already been given in Prof. Irving's explanatory note at the beginning of this paper, in which is included also a summary of the different views held by various writers with regard to the stratigraphical position and origin of the rocks of the greenstone-schist area, which forms the subject of this part of the present essay. In connection with this account has also been given a geological map of the Marquette region, compiled by Professor Irving from the maps of Brooks and Rominger and from original observations of his own. (Pl. I.) It will not therefore be necessary for me to present anything further as to these general matters in the present connection.

Special references to the petrographical work of others on the Marquette rocks will be made in the course of the following detailed descriptions.

In some respects the greenstones of the Marquette area seem peculiarly suited to throw light upon the dynamic metamorphism of basic eruptives, since a portion of these rocks seem to have been extruded both during and subsequent to the action of the metamorphosing forces. Hence we find the same eruptives in different stages of alteration. Moreover, fragmental material (tuff) of the same nature and origin of the massive rocks is abundantly developed, and this too shows varying stages of consolidation into masses which closely resemble the solid rock. This great variety, while it is full of interest and suggestions of new possibilities, is frequently very confusing. It often becomes impossible to speak with certainty about the origin of a rock which, on account of its many analogies, we may regard as having been produced in several different ways.

The general similarity of the greenstone schists of the Marquette and Menominee areas will be brought out in the following pages. It is worthy of mention that the greenstone schists of both of these regions have a strong resemblance to some of the greenstones and agglom-

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erates of the extensive group of rocks occurring on the Lake of the Woods and on Rainy Lake in Canada, to which Mr. Andrew C. Lawson, of the Canadian Geological Survey, has given the name of Keewatin series. This series he regards as belonging immediately beneath the Huronian, which is represented in those northern regions by the so-called Animiké series.[1] This is also the position which the greenstone schists of Marquette occupy, since they quite unmistakably underlie the iron-bearing detrital rocks, which, according to Irving, are the equivalents of the true Huronian. According to Irving also the greenstone schists here probably underlie the overlying iron-bearing series unconformably.

The Marquette greenstone-schist belt, which at the lake shore is between 2 and 3 miles wide, extends to the westward for about 6 miles, without materially altering its form or width. It then broadens suddenly by a wide extension toward the north, and at the same time is divided into two portions by the eastern extension of a narrow arm of granite (See map, Pl. I). The southern of these portions continues a due westward course with an average width equal to that of the entire belt before its division. The northern portion is separated from the southern, first by granite, and then to a greater and greater extent by a large, wedge shaped area of the rocks of the overlying iron-bearing or Huronian series.

For convenience in arranging the following petrographical descriptions the ground covered has been divided into four areas, which will be considered in order: (1) The *eastern* area, near Marquette; (2) the *western* area, immediately north of Teal Lake, in the town of Negaunee; (3) the *northern* area, lying north of Dead River, and (4) the *Deer Lake* area, a short distance north of the town of Ishpeming. The last named area was not studied by the writer in person, specimens from it, with full descriptive notes, having been sent to him by Professor Irving for comparison with the collections which the writer had himself made in other areas.

In the eastern or Marquette area the whole width of the greenstone belt, including the granite contact on the north, was studied for a distance of 3 miles west from the lake shore. In the western or Negaunee area two sections were run northward across the greenstone-schist belt, one passing through Secs. 21, 28, and 33, T. 48 N., R. 26 W.; the other through Secs. 13, 24, 25, and 36, T. 48 N., R. 27 W. In the northern area the examinations made were carried on from a camp situated in Sec. 9, T. 48 N., R. 26 W., and embraced the area covered by Secs. 3, 4, 5, 8, 9, 10, and 11 of this township.

The first of these areas is the most varied in its petrographical characters, and it was, therefore, the most thoroughly studied. It is

[1] See General Report of Progress of the Geological Survey of Canada for 1885; also of Am. Jour. Sci. (3d series), vol. 33, 1887, p. 473. I am indebted to Dr. Lawson for the opportunity of examining the extensive suite of the Rainy Lake rocks, upon the microscopical study of which he was engaged in the petrographical laboratory of Johns Hopkins University in the winter of 1886-'87.

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divided into two portions of nearly equal extent by the narrow east and west band of iron-bearing slates, to which Rominger applied the name of Eureka series. The northern portion of the Marquette area, extending from Lake street, Marquette, northward to the granite, is in large part composed of banded greenstone schists, having an east and west strike, and a steep northern dip. They are most conveniently seen in typical development on Lighthouse Point. The layers of these rocks are alternately of a darker and lighter shade of green, which gives these particular greenstones their characteristic striped appearance. In these banded rocks of the northern part of the Marquette area intrusions of comparatively little altered acid and basic matter are abundant. These are for the most part conformable to the bedding of the schists and embrace granites, gneisses, schistose porphyries, diorites, and diabases. Whenever, in these undoubtedly eruptive rocks, a schistose structure is apparent, this is conformable to the bedding of the banded greenstone schists.

The southern portion of the area about Marquette, on the other hand, is occupied by much more massive and homogeneous greenstones of a nearly uniform light green color, and an almost aphanitic structure. These are characterized by their division into oval or lenticular areas which interlace and which are separated by a finely schistose material of much finer grain. This peculiar parting, which, according to the writings of the Canadian geologists, appears to have a very widespread distribution through the greenstones of the Northwest, at first glance resembles the spheroidal weathering of many eruptive rocks. There is, however, better reason for regarding it as of mechanical origin, as will be more fully explained in Chap. V.

The schistose structure of the southern Marquette greenstones is of secondary origin, due, probably, in almost every case, to pressure, while anything like the banding or striping of the more northern rocks is here wholly wanting. Intrusive rocks are rarer than in the banded greenstones of the northern portion of this area. When such dikes do occur they are much more altered and hence approach closely to the enclosing rock—a fact which renders their detection difficult.

The two portions of the Marquette greenstone area are therefore broadly distinguished in many of their petrographical characters. The east and west band of iron shales, mentioned above as separating them, extends from the north side of Marquette harbor (Lake street) westward along the northern side of the Duluth, South Shore and Atlantic Railroad. They seem to be identical with certain members of the iron series and at one point, about two miles west of Marquette, they actually contain quite an extensive deposit of hematite. It is here that the Eureka shaft was sunk at an early date in the history of iron mining in the Marquette region, and from this Dr. Rominger has taken his name for this series of Huronian beds. To make the references to localities in the Marquette area more intelligible, a sketch map of the environs of the city is here appended, Pl. VII.

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With reference to the other two areas examined it is here sufficient to say that the greenstones of the western or Negaunee area more closely resemble those exposed in the southern portion of the Marquette region; while the rocks encountered in the northern area show many points of likeness to those occurring north of Marquette.

ROCKS OF THE NORTHERN PORTION OF THE MARQUETTE AREA.

BASIC INTRUSIVES.

Diabase.—Diabase in well defined dikes of various sizes is an important feature in the geology of the northern portion of the Marquette greenstone area. This rock occurs in all stages of preservation from an unaltered condition to a hardly recognizable aggregate of secondary and decomposition products.

In all the freshest specimens examined olivine is present, but with the commencement of alteration this mineral is the first to disappear In many cases, therefore, where the rock may still be recognized as a typical diabase, it is now impossible to say whether it was originally olivine-bearing or not.

The next stage in the alteration is marked by the change of the pyroxene to uralite, and the more or less synchronous passage of the feldspar into saussurite and of ilmenite into leucoxene.

Still later follows the development of such final decomposition products as chlorite, epidote, calcite, quartz, etc. The extent to which these chemical changes destroy the original diabase structure differs in different cases. As a rule this remains distinct during the first two stages of alteration, while it generally, though not always, disappears during the third. In some instances a pronounced schistose structure has been developed in undoubted diabase dikes by extensive alteration.

The Great Dike.—The best material for the study of the fresh olivine diabase near Marquette was obtained from the great dike which forms the center of Lighthouse Point (see Pls. I and VII). Here its eruptive character may be admirably seen by the sharp line of contact which it presents with the adjoining banded green schists. This dike may be traced by several outcrops along Michigan street in Marquette, and then as a high, rocky ridge which extends for some three miles westward, through Sections 15 and 16, just north of the main road from Marquette to Negaunee.

From various portions of this dike nine specimens were collected. The four freshest of these specimens (Nos. 11617 and 11622, from Lighthouse Point; No. 11636, from Lighthouse Point quarry, and No. 11666, from a cutting on Michigan street) are not to be distinguished from one another.

The structure of this work is the hyp-idiomorphic diabase structure,[1] which forms one of the most certain characteristics of this group

[1] "Structure ophitique" of Fouqué and Michel-Lévy, "Divergent-strahligkörnige Structur" of Lossen, and "Diabasischkörnige Structur" of Rosenbusch.

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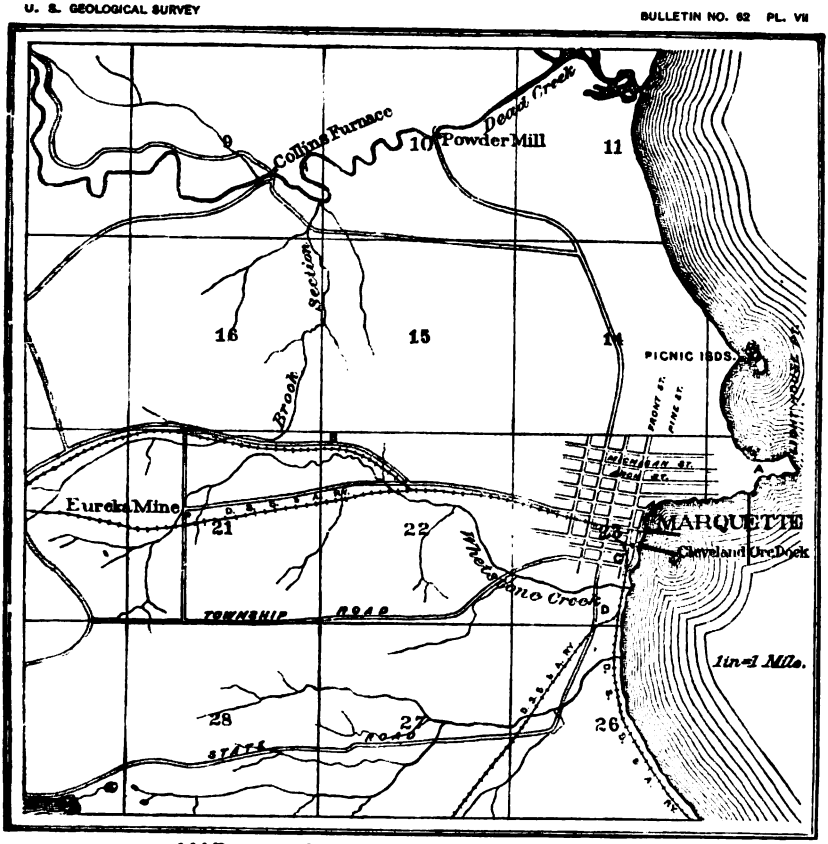

MAP OF THE ENVIRONS OF MARQUETTE

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of eruptives. The grain is of medium coarseness. The lath-shaped plagioclase crystals measure from 1.5 to 1^{mm} by 0.25 to 0.15^{mm}. The interstices between these are filled with augite and ilmenite. The mineral components observed under the microscope are, in order of their age, as follows:

Essential: Olivine, labradorite, augite, $\left\{\begin{matrix}\text{Ilmenite,}\\ \text{Magnetite.}\end{matrix}\right\}$

Accessory: Apatite, hornblende, biotite, quartz.

Secondary: Serpentine, uralite.

The olivine is mostly in rounded grains or in irregular areas, although it sometimes shows evidences of a crystal form, especially the acute angle due to the intersection of two dome faces (notably in No. 11666). It is commonly wholly changed to serpentine, but in a few instances remnants of the original transparent olivine substance remain.

The feldspar is always a plagioclase with the peculiar elongation of the crystal in the direction of the brachydiagonal axis, which is characteristic of diabase. The crystals are always striated, often minutely so. The extinction is generally sharp, although an undulatory extinction is sometimes observed.

The augite is quite normal for diabase. It is of a light, slightly reddish shade of gray, with a perfect cleavage parallel to the prism. Twins are very common, and the line of the lamellæ may be seen in ordinary light traversing the basal sections and bisecting the cleavage angles. In polarized light the colors distinguishing the twin lamellæ are very brilliant. No crystal form is ever recognizable, the mineral being typically "xenomorphic," in the sense used by Rohrbach.[1]

Quartz is rare in diabase, but where it occurs as it does in No. 11666 we must regard it as an original constituent, on account of the extreme freshness of the whole specimen.[2]

The iron oxide is entirely opaque and shows a very irregular outline. This is mostly due to the penetration into it of the feldspar crystals whose form is clearly shown. Its crystallization must therefore have been subsequent to that of the feldspar, and was apparently about synchronous with that of the augite. The oxide itself is probably partly ilmenite and partly a titaniferous magnetite. In none of the freshest specimens does it show trace of leucoxene. It is, however, sometimes partially surrounded by a border of biotite.

Original hornblende is rare in this rock, but traces of it were observed in a few instances.

Among the alteration products serpentine is abundant wherever olivine existed, but the rock is still too fresh to show more than the most occasional uralitization of the pyroxene.

The five other specimens collected from this great dike show more

[1] Tschermak's mineral. u. petrog. Mitthell., vol. 7, 1885. Rohrbach's two terms, "authomorphic" and "xenomorphic," adopted by Kalkówsky (Lithologie, 1886, p. 14) were replaced by Rosenbusch in the last edition of his Massige Gesteine by "idiomorphic" and "allotriomorphic," though for what reason is not apparent.

[2] Cf. Rosenbusch, Mikros. Physiog., 2d ed., vol. 2, 1886, p. 188.

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altered forms or abnormal varieties of the same rock. They are as follows:

No. 11621, glassy diabase.
No. 11675, granophyre diabase.
No. 11672, uralite diabase (structure intact).
No. 11615, uralite diabase (structure intact).
No. 11610, epidiorite schist (structure gone).

No. 11621, collected near No. 11622 from the side of the great dike on Lighthouse Point, is a glassy modification of the diabase, produced by the rapid cooling of the molten mass against the inclosing walls. The microscope shows this rock to be composed of a very dark brown glass, which can be rendered transparent only with the greatest difficulty. This opacity is due to the accumulation of minute globulitic bodies, which can be detected only with the highest magnifying power in the thinnest parts of the slide. Traces of the arborescent and fern-like forms common in basic glasses (tachylite) are easily recognizable. The only mineral constituents which have crystallized in this rock are olivine and feldspar. The former shows well defined crystals. These frequently contain inclusions of the brown glass, and are now wholly changed to a yellowish green serpentine. The feldspar shows the narrow, lath-shaped, and but partially completed crystalloids and skeleton forms which abound in all glassy rocks. These are filled with either penetrations or inclusions of the brown, glassy base.

The chemical constituents of the other diabase minerals—augite, ilmenite, etc., are still present in the glass.

No. 11675 presents an unusual modification of this diabase. The specimen was collected from the high, rocky ridge which is formed by the great dike in the southern part of Section 16, about one and a half miles west of Marquette. The hand-specimen is browner than is usual in this diabase and is speckled with reddish spots. Under the microscope the grain is found to be of the usual coarseness and the rock itself slightly more altered than the specimens above described.

The structure of the rock is still perfectly preserved. The ilmenite is unaltered, and, as before, is frequently fringed with biotite. The feldspar is clear and its twinning striations are very distinct, although it is traversed by many interlacing veins of a green chloritic alteration product. There are no certain traces of olivine in this rock and the augite has undergone extensive change to a brownish yellow hornblende. This is partly fibrous, but also in part quite compact. Indeed, this rock offers a noteworthy instance of the apparent change of augite directly into compact brown hornblende. Much more of this mineral is here present than in any of the fresher specimens examined. It is impossible to assert positively that some of it did not exist as an original component of the rock, but the frequent cases of its undoubted derivation by paramorphism of the augite makes it at least probable that all the hornblende has originated in this way.

The reddish spots spoken of as visible in the hand-specimen represent another interesting feature of this rock. They are shown by the micro-

scope to be areas of a regular intergrowth of feldspar substance and quartz. This is sometimes in the form of granophyre. i. e., in slender fibers, which group themselves in radiating tufts about a clear feldspar crystal, and sometimes it shows the structure called micropegmatite. This latter consists of small angular areas of quartz, each having the same optical orientation, which are embedded in the reddish globulitic feldspar substance.[1]

Quite recently Mr. Waldemar Lindgren has described a similar structure in a diabase from the Big Belt Mountains, Montana.[2]

It was also observed by the writer some years ago in a diabase from Pleasant Valley, New Jersey, a specimen of which he received from Mr. J. F. Kemp, of Cornell University.

Rosenbusch[3] regards this structure as sufficient proof that the quartz is original, but the observations of Irving[4] in the Keweenawan felsites and others make this conclusion doubtful.

No. 11672, collected at the corner where the road running west from Collins Furnace joins the road leading to Bancroft on the Dead River (center of Sec. 17, T. 48 N., R. 25 W.), is a uralite diabase, whose structure is still perfectly preserved.

The large crystals of idiomorphic feldspar are in part clear, but to a considerable extent clouded by the development of saussurite.

The allotriomorphic augite is in some cases intact or remains as a core in the center of the secondary hornblende which has been derived from it. More frequently, however, the hornblende or uralite has wholly replaced the pyroxene. Its structure is oftener compact than fibrous, and its form reproduces exactly that of the original augite. Quartz areas are not uncommon. The ilmenite is mostly changed to leucoxene. Near one large grain of the latter is seen an area of brown mica, which is filled with a sagenitic network of minute rutile needles.

No. 11615, from an outcrop of this same great dike, at the bottom of the hill, which forms the eastern end of Arch street, Marquette, represents the next stage of alteration in the diabase.

The original structure is still plainly recognizable, although it is beginning to be concealed by alteration.

The feldspars exhibit their characteristic lath-like forms, but the sharpness of the outlines and more or less of the internal substance is clouded by secondary products. These seem to be for the most part small hornblende needles which have wandered in from the alteration of the pyroxene, but in some places epidote is also developed from the alteration of the feldspar itself. Still, in nearly every case enough of this unchanged feldspar is present to show plainly its original form and twinning structure.

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[1] This peculiar structure was first observed in diabase by Törnebohm in 1877 (Neues Jahrbuch für Mineral., 1887, p. 262), who found it in his Konga-diabase type of southern Sweden, and named it "Schriftfeldspath."

[2] Tenth Census Repts., U. S., vol. 15, 1887, p. 736.

[3] Mikros. Physiog. 2d ed., vol. 2.

[4] Cf. Mon., U. S. Geol. Survey vol. 5, p. 114.

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The augite is in the process of changing to hornblende. This alteration is sometimes complete, but oftener cores remain in the center of what was the original pyroxene crystal. The border of hornblende is double, consisting of a wider internal band of yellowish brown fibers which have apparently resulted directly from the augite substance, and a narrower, outer zone of bright emerald green, pleochroic needles which seem to project into the surrounding feldspar.[1] The individuals of the inner zones are much smaller than those of the outer, and form a confused, felt-like mass, while the external needles as a rule have their longest axes parallel. These needles are most developed in the direction of the vertical axis of the augite. They may owe their different coloring to the influence of the feldspar substance which has contributed to their formation. In some cases the secondary hornblende appears to be homogeneous over considerable areas, exhibiting a uniform extinction and a comparatively compact character. This can not, however, be regarded as original in its nature.

The ilmenite still retains its form but is largely changed to leucoxene.

No traces of olivine were found in this rock, probably because of its altered condition.

No. 11616 is instructive when taken in connection with the specimen last described, No. 11615. Both were collected from the large and smoothly glaciated surface of trap, exposed at the east foot of Arch street. Through the massive rock run a number of schistose bands, produced by crushing and shearing along lines of weakness. One of these bands furnished the present specimen. There can be no doubt that these bands are a part of the massive rock. Both were the same before the schistose bands were produced by more intense mechanical and chemical action.

Under the miscroscope the appearance of these two specimens is found to accord fully with their field relations. The original diabase structure, so distinct in the massive rock, has wholly disappeared in the schistose one. There are no traces of lath-shaped feldspar left. The rock is mainly composed of a confused network of fibrous, very pale green and slightly pleochroic hornblende needles. These are sufficiently parallel in their arrangement to produce the schistose structure of this rock. They are secondary—formed from the alteration of the augite or the joint alteration of the pyroxene and feldspar—as may be admirably seen in section No. 11615, where they are in the process of formation. Scattered among this hornblende, is considerable cloudy and nearly opaque saussuritic substance, mixed with more or less secondary quartz, both of which have been derived from the feldspar. The ilmenite also has undergone an interesting alteration and is here represented by cloudy leucoxene, with only occasional opaque black dots of the original mineral. This substance is arranged in long stringers and shreds which follow the direction of the schistose structure.

[1] On the production of a similar double uralite zone around pyroxene. See Lossen: Erläut. z. geol. Specialkarte von Preussen u. d. thüring. Staaten, Blatt Harzgerode, p. 81, 1882; and Williams: Bull. U. S. Geol. Survey, No. 28, p. 42, Pl. I, Fig. 2.

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Here we have an undoubted instance of the dynamic metamorphism of a diabase, where every stage in the process can be followed. Every mineral of the schist can with certainty be traced to its original form, and yet the chemical alteration has been accompanied by such a change of position (migration) that the original structure has wholly disappeared and a new and different structure has been produced. This derived rock is quite identical with some of the most characteristic so-called hornblende or actinolite schists.

The chemical action has here been proportionately increased by the crushing. This seems true for all the constituents, as there are no traces of the fresh fragments of broken feldspar crystals which were so often observed in analogous greenstones of the Menominee region.

There is an excellent section through the rocks of the northern portion of the Marquette area, exposed by a brook which flows northward almost along the line between Sections 15 and 16 (hardly over a mile west of the city) and empties into Dead River. Between the road leading from Marquette to Collins's Furnace and that forming the main highway to Negaunee, this small stream has excavated a deep ravine, upon the high, steep sides of which the relationship of the different rocks is admirably diplayed. This locality is described by Dr. Rominger,[1] and for convenience we will in future allude to it as the Brook section. (See Pl. VII.)

Here were encountered several exposures of fresh olivine diabase. One of these, No. 11708, was taken from the branching dike in the wall of greenschist and granite, which Rominger has described and figured.[2] This rock resembles the freshest specimens obtained from the great dike, except that its grain is finer, as might be expected in a mass of so much smaller size. No trace of alteration is here visible, except in the olivine. This constituent is not abundant, but it occasionally appears in well shaped crystals, which are completely changed to yellow serpentine. The iron oxide presents in its form a decided contrast to that above described. In this rock it was produced much earlier than in the other, and hence it has a well developed crystal form. This, as seen under the microscope, is square (octahedral section), which may be an indication that the mineral is magnetite instead of ilmenite, as before. The feldspar and pyroxene of this rock need no special comment.

No. 11719, obtained near the edge of another dike not far from the last mentioned one, is only semi-crystalline. Its brown, glassy base resembles that of No. 11621, but crystallization is farther advanced. The sharply defined olivine and feldspar crystals are quite the same, but a vast number of smaller feldspar crystals are here developed in the base. Only a very little augite, and that in rounded grains, is present. This rock would be correctly termed a melaphyre.

[1] Geol. Michigan, vol. 4. p. 25.
[2] Ibid., p. 148.

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No 11679 is from the center and No. 11680 from the edge of a dike of porphyritic greenstone, which intersects the banded greenschists on the western side of the Brook section, not far from its southern end.

The first of these rocks has a coarsely porphyritic structure, which, on account of its altered condition, is only prominent on a weathered surface. A fresh fracture appears of an almost even gray color, resembling some of the finer greenstones. Under the microscope this specimen is found to correspond admirably to the descriptions of the rock-type, named by Gümbel "epidiorite." The augite, reddish brown cores of which still remain, is largely changed to fibrous hornblende. This mineral is mostly of a pale brown color, but often has a bright green edging where it adjoins the feldspar substance, as has already been noted in the case of No. 11615 (p. 141). The feldspar is still clear and fresh, showing the characteristic lath-shaped forms of diabase. It is only rarely clouded by small patches of a gray saussurite. Much more abundant in this feldspar are veins and small areas of green hornblende needles, which owe their existence mostly to the pyroxene, though the feldspar seems also to have aided in their formation. They are especially abundant in cracks, along which the substance appears to have wandered from the decomposing augite. This hornblende is finely fibrous and forms matted, felt-like masses. There is but little chlorite and secondary quartz in this rock. The ilmenite is largely changed to leucoxene and occasionally surrounded by a rim of biotite.

The second of these two specimens (No. 11680) from the edge of this dike, shows an extremely fine grained, greenish groundmass, whose components are very weakly polarizing and hardly determinable. This was perhaps once a glass which has become devitrified and viriditic. In it are imbedded sharp, lath-shaped plagioclase crystals, which are either unaltered or at most penetrated by veins of actinolite needles, and augite almost wholly changed to hornblende or chlorite.

The following five rocks are also good representatives of the epidioritic type. They are largely composed of either light or dark green, fibrous, secondary hornblende. In none of them does any trace of augite now remain, and it is possible that some of them were originally true diorites, like the rocks to be described under the next head. However, the unmistakable evidences of diabase structure often apparent render it more probable that these rocks all belonged originally to this type.

No. 11663, from Pine street just north of Michigan street, Marquette, is most like a true diorite and may be an altered form of the Picnic Island rock. The hornblende is of the general type represented in Pl. XII, fig. 2 of No. 11186, from the Horse Race above Upper Quinnesec Falls (see p. 107). It is more or less fibrous, of a pale green color and often looks as though it had originated from the bleaching and disintegration of a compact original hornblende. Around the edge of large areas it has a darker green border and seems to ravel out into fine fibers which

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wander into the feldspar. Indeed, the feldspar is quite filled with such hornblende needles, which, together with its saussuritic alteration products, almost conceal the original substance. Ilmenite in ragged areas, but without leucoxene, and a little of the chlorite-epidote aggregate (see Pl. XI, fig. 1) are also present.

Nos. 11712 and 11720, both from the Brook section, are rocks of the same general character as that last described. The former is decidedly schistose and bears much internal evidence of the action of great pressure. All of the constituents are arranged in interlacing and elongated bands. The feldspar is much crushed and shows the peculiar mosaic due to secondary crystallization. It is also often changed to a granular aggregate of brightly polarizing, pale green epidote grains. The hornblende crystals are broken and bent, and especially around their outer edge, are very frequently reduced to a confused mass of fine needles which have extensively wandered out into the feldspar substance. The ilmenite also is much crushed and elongated in the direction of the schistosity, but it shows no indication of being changed to leucoxene.

The second specimen, No. 11720, is somewhat schistose, though less so than the last. It is extremely dark in color owing to the large proportion of iron which enters into its composition. Under the microscope it is a confused aggregate of very dark green and strongly pleochroic hornblende needles, a little feldspar, proportionately much ilmenite and quartz. Some of the larger hornblende crystals show the peculiar granulated center, lately described and figured by me from the gabbro-diorites occurring near Baltimore,[1] to which indeed this specimen presents many points of close resemblance.

The two remaining specimens are much more altered than those just described.

No. 11661, found beside the granite boss (the so-called "gold mine") just west of Pine street, Marquette, is coarsely granular. The feldspar is altered to saussurite or calcite. The hornblende is pale green and partly fibrous. The center of the crystals is frequently composed of a dark, yellowish green substance which hardly polarizes at all. This, at first glance, appears to be a core of compact brown hornblende but a closer examination shows that this is not its nature. A little sphene and considerable blood red iron hydroxide make up the remainder of this rock.

The last specimen of these epidioritic rocks, No. 11711, was part of a well marked dike of schistose greenstone which intersects a boss of gneiss near the northern end of the Brook section. This gneiss strikes E. and W., while the dike strikes N. 75° E. The schistosity of the latter is parallel to its walls, so that the foliations of the two rocks intersect at an angle. This rock shows the effects of pressure and crushing. It is now a finely granular aggregate of pale green fibrous hornblende, feldspar, quartz, calcite, and leucoxene.

[1] Bull. U. S. Geol. Survey, No. 28, p. 28, Pl. III, fig. 1.

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Diorite.—The occurrence of typical original diorite in the Marquette area still seems a little doubtful. No. 11654, which composes the Picnic Islands, a short distance north of Lighthouse Point, comes nearest to deserving this name, although this rock might with as much propriety be termed an amphibole granite. Julien called it a "quartzose porphyritic diorite,"[1] and he was followed by Wadsworth.[2] The microscope shows this rock to be a coarsely granular aggregate of green hornblende, saussuritized plagioclase, together with a less altered, unstriated feldspar, quartz, and sphene. The hornblende is mostly quite compact, and shows in cross-section sharp crystalline outlines, which are often twinned. The plagioclase contains large zoisite individuals aside from its more usual saussurite aggregate. The unstriated feldspar seems to alter to muscovite or kaolin, as is common in orthoclase. Seams in this rock are filled with epidote, calcite, or more rarely specular iron.

The Picnic Island rock seems to be most closely related to the amphibole-granites, gneisses, diorites, and massive hornblendite which occur in the granite farther north—notably on Partridge or Middle Island, beyond Presqu' Isle. At this latter locality there is every evidence, from the intimate association of the granite and these hornblendic rocks, that they were both liquid, or at least plastic, at the same time. Such a perfect intermingling of the two magmas it seems impossible to explain on any other hypothesis; nor, indeed, are indications of the same intermingling wanting on some of the Picnic Islands.

ACID INTRUSIVES.

General character.—The association of acid rocks of various types with the greenstones of the northern portion of the Marquette area is not less intimate than that already described as occurring at Upper Quinnesec Falls, on the Menominee River. (Chap. III, p. 110.) The general character of these rocks is very similar at both localities, and at both they offer equally valuable material for the study of dynamic metamorphism.

The passage from the Marquette greenstones to the granite lying north of them is an extremely gradual one. There is no such sharp line of contact as is represented on Rominger's map, but, on the contrary, as Rominger himself explains, there is a complete interpenetration of the two rock masses. The granite has intruded itself into the schistose greenstones, for the most part following their bedding and forcing apart their strata. The amount of the acid rock gradually diminishes as we go southward. At the Dead River it still composes over half of the entire mass, but between this and the city of Marquette the dikes and bosses of granite grow less and less frequent. They are,

[1] Geol. Mich., vol. 2, p. 163.

[2] Notes on the Iron and Copper Rocks of Lake Superior. Bull. Mus. Comp. Zool., Harvard Coll. Whole Series, vol. 7, Geol. Series, vol. 1, p. 39.

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however, never entirely absent from the northern part of the greenstone area, but extend to the limits of the Eureka series. Around Lighthouse Point and near the Marquette water-works, on the north side of the harbor, bands of reddish and gray acid rocks may be seen along the lake shore in abundance. Some of these are but little altered granites and porphyries, while others are decidedly schistose and seem to owe their structure to dynamic agencies.

Granite.—We will first examine specimens of the unaltered granitic type. These can be nowhere better seen than in the neighborhood of the powder mill on Dead River, near the center of Section 10. Near this place were obtained Nos. 11612 and 11613, both normal granites which penetrate the schistose greenstones. They are of a reddish color and consist principally of feldspar and quartz, both of which are allotriomorphic and form a granular aggregate of interlocking grains. The quartz areas are often composite, and are traversed by lines of fluid-cavities, containing movable bubbles. The feldspar is both monoclinic and triclinic. It is considerably altered to muscovite or kaolin. A little chlorite represents the original presence, in small quantity, of a third constituent, but its condition is now too much altered to allow of its exact determination. The second of the two specimens (No. 11613) is the coarser grained and contains both microcline and pyrite, which are lacking in the former.

No. 11668, also from near the powder mill, occurs where the granite and schistose greenstones are very intimately associated and it seems to be intermediate between them. Under the microscope it appears as a reddish granite, like those last described. Apatite crystals and minute, sharply defined zircons are abundant. The greenish color, which imparts to this rock an appearance intermediate between a granite and a greenstone, is due to the large amount of chlorite present. This sometimes traverses the feldspar in irregular veins and is sometimes massed together in larger areas, as though it had resulted from the alteration of some bisilicate, or, as is still more probable, of a micaceous constituent.

Toward the southern end and on the west side of the Brook section, the banded greenstones and granite are exposed in relations not less interesting than those to be seen at Dead River. A large, glaciated surface of the schists shows intrusions of both granite and diabase which cut directly across the strike. The former rock contains angular fragments of the schist and in one case it fills the inequality formed by the faulting of the schist along a joint plane nearly perpendicular to its bedding. It also forms narrow veins and rows of bulging lenses in the schist. This granite shows no signs of foliation in the field, but a closer study of it in the laboratory discloses the effects of powerful dynamic action. The hand-specimen, No. 11678, proves upon microscopical examination to be an excellent example of peripheral granulation, producing what Törnebohm has called the "mortar-structure." The grains

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have rubbed against one another and formed a fine mosaic—mostly a new crystallization—which resembles a cement. The quartz has suffered so much by this process that hardly a trace of the original granitic quartz remains. The feldspar presents rounded grains, often bent or fissured. In the cracks thus formed the same mosaic-like cement is developed. Chlorite, epidote, muscovite, and iron hydroxide are present in this fine grained mass between the rounded feldspars.

No. 11710 was obtained from the rounded knob of gneissoid granite, near the northern end of the Brook section, through which the dike of foliated trap described on p. 145 (No. 11711) passes. In this rock the gneissic structure is quite prominent through a parallel arrangement of the constituent minerals, but under the microscope it quite closely resembles the last specimen. The same peripheral granulation of the original grains by rubbing is even more apparent; and, although there is no marked tendency to parallel arrangement visible in the thin section, the effects of pressure are everywhere shown, as in the undulatory extinction of the quartz, in the production of secondary strain-lamellæ in the feldspar, and in the presence of microcline.

No. 11614 was obtained from a gray granitic knob on the lake shore at the mouth of Dead River. This is penetrated by several sharply defined dikes of fine grained diabase, and, like the rock last described, is decidedly gneissoid in structure. The rock is composed mainly of quartz and orthoclastic feldspar, although both plagioclase and a green fibrous hornblende are also present. The gneissic or "flaser" structure is its most striking feature. This is plainly visible in the thin section and seems to be mainly due to the elongation of the quartz areas in the direction of the foliation. This mineral has suffered greater deformation than the feldspar and is present in long, lenticular patches, whose axes are often sinuous. These are for the most part composite and always show an undulatory extinction. There is, strangely enough, no peripheral granulation visible in this rock.

No. 11660 is from a granite boss on the west side of Pine street, north of Ohio street, Marquette. A fine section has recently been laid open through the center of this mass by some eager gold seeker. The rock is a fresh, even grained aggregate of orthoclase and quartz. Any original micaceous constituent seems to be lacking, although good-sized plates of muscovite have been secondarily developed at the expense of the orthoclase. This feldspar possesses a beautiful zonal structure, which is brought out in unusual distinctness by the different degrees to which the alteration has progressed in different zones. The eruption of this rock must have taken place subsequently to the dynamic movements which metamorphosed so many of the Marquette intrusives. It shows no evidence of pressure in its microscopic structure, although No. 11658, collected but a few feet north of it, from a narrow band of acid rock, shows such evidence in a very marked degree.

Quartz porphyries.—No rocks are better suited to exhibit the effects

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of dynamic metamorphism than the quartz porphyries. Some of the more important results which this class of rocks has yielded to European students have already been stated in Chapter I. Near Marquette the narrower of the dikes and intrusions of granitic matter have, in consequence of their rapid cooling, assumed this form. Almost every variety of structure between a typical granite and quartz porphyry may be found by comparing specimens from the different exposures. Furthermore, the various dikes seem to have been subjected to different degrees of mechanical action, so that the successive phases of metamorphism may be traced by a comparative study of them.

In No. 11629 we have a granitoid porphyry which has suffered much from chemical, but very little from mechanical alteration. This was collected from a branching dike of a massive, reddish rock, exposed on the lake shore near the water-works in Marquette. It approaches a granite in being largely composed of porphyritic feldspar crystals with but comparatively little interstitial groundmass. What there is of this groundmass consists of a fine granular mosaic of quartz and feldspar grains with some sericite. The larger feldspar crystals are colored red by an abundance of fine globulitic dust. They also show an advanced stage of chemical alteration in the development in them of a micaceous mineral (sericite). The only traces of the original biotite consist of chlorite areas dotted over with iron hydroxide. At first glance this rock seems to resemble No. 11678 (above described as a fine example of Törnebohm's mortar structure), but a closer examination shows that the structures, apparently so much alike, must have been produced by very different means. There is in the present instance no evidence of pressure, the feldspar crystals have their original outlines intact, and the interstitial mosaic, instead of being due to a grinding action between the grains, is here evidently a product of the original crystallization.

The next specimen, No. 11620, is a typical quartz porphyry which also has been but little modified by the effects of pressure. It is from a small dike at the eastern extremity of Lighthouse Point and is a much fresher rock than the last. The porphyritic crystals are both smaller and less frequent. They consist of orthoclase, plagioclase, and quartz, imbedded in an abundant microgranitic groundmass. The orthoclase often shows a twinning structure in accordance with the Carlsbad law and is extensively altered to muscovite, large plates of which occur around its crystals. The quartz does not here possess its characteristic dihexahedral form, but occupies oval or irregularly shaped areas which are frequently composite.

These two specimens will serve as representatives of those acid dike-rocks which have been least modified by pressure. They will serve as a starting point for tracing the successive stages of this action in the following specimens. The changes observed are: The deformation and elongation of the quartz crystals; the fracturing and separation of the fragments of feldspars; the parallel arrangement of the new crystalliza-

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tion products, giving rise to a gneissic or "flaser" structure; and the development of a cleavage. The intensity of these changes is of course proportionate to the amount of force exerted.

No. 11633, obtained from the quarry on Lighthouse Point (A of map, Pl. VII), is a quartz porphyry which differs only slightly from No. 11620, last described. Its groundmass is somewhat finer grained and sericitic. The porphyritic crystals of feldspar are nearly the same, but the quartzes are deformed and lenticular, sometimes with only an undulatory extinction, sometimes broken into several areas which are more or less displaced from their original position. Although the thin section shows no indications of schistose structure, this in the field is quite pronounced. The rock occurs in the green schist, in small bands, which wedge out very soon. It has a decided tendency to break along planes parallel to the schist-bedding, and upon these planes of parting sericite is abundantly developed.

No. 11653, from the northern edge of Lighthouse Point, just below the Lighthouse, is very similar to the last, except that here a schistose structure is microscopically, as well as macroscopically, visible. The groundmass and porphyritic crystals are quite identical with those above described. In the former there is a brown mica abundantly developed in aggregations of little plates, which form sinuous lines around the porphyritic crystals in a direction parallel to the strike of the surrounding greenstone schists. This fact is mentioned by Dr. Wadsworth, who was the first to discover these rocks.[1]

Nos. 11707 and 11717, were collected from two dikes of porphyry interlaminated with the green schists of the Brook section. In the hand specimens they exhibit no marked foliation, but under the microscope their evidences of mechanical alteration are most interesting and instructive. The groundmass is of the same character as that already described. In it, however, are sinuous bands of green mica which bend and wind about the porphyritic crystals so as to produce a decided "micro-flaser" structure. This feature is more pronounced in the second specimen, although the two are essentially the same. The microscopic appearance of 11707 is represented in Pl. XV, fig. 2. The porphyritic feldspars have suffered little or no change, unless it be by the production of microcline which is quite abundant in the center of some of the crystals of No. 11707. The quartz has suffered much more deformation—a fact which the observations of J. Lehmann[2] and Ch. E. Weiss[3] would indicate to be the rule in rocks of this character. In the present case the quartz is drawn out into long, spindle shaped lenses which are often pinched at their ends into fine lines that bend around the other porphyritic crystals (see Pl. XV, fig. 2). This deformation, however,

[1] Notes on the Iron and Copper Rocks of Lake Superior. Bull. Mus. Comp. Zool., Harvard Coll. Whole Series, vol. 8, Geol. Series, vol. 1, p. 38.

[2] Untersuchungen über die Entstehung der altkrystallinischen Schiefergesteine. Bonn, 1884.

[3] Zeitschr. Deutsch. geol. Gesell., vol. 29, 1877, p. 418, and Jahrbuch preuss. geol. Landesanstalt für 1883, p. 213. Cf. Rosenbusch: Mikros. Physiog., 2d ed., vol 2, 1887, p. 412.

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does not take place without the loss of continuity in the quartz substance. On the contrary a mosaic-like aggregate of interlocking grains is formed whose optical orientation differs more and more in proportion as the original quartz crystal is elongated. In cases where the deformation is slight, only a disturbed extinction results, as may be seen in No. 11753. The presence of interlocking grains of different orientation, as in this instance, would indicate solution and subsequent deposition.

No. 11658, from a narrow acid band immediately north of the granite boss near Pine street, Marquette, is a rock of precisely the same type as those just described but which shows a secondary schistose structure more perfectly developed than any of the preceding. The brownish or greenish mica is here arranged in nearly parallel bands which bend only slightly around what were once porphyritic feldspar crystals. These latter have undergone an almost complete change to muscovite and quartz aggregates, some of which are now drawn out into long lenticular areas. These patches are hardly to be distinguished from the groundmass, except by their coarser grain, and yet they can be traced with certainty back to the original orthoclase. Sharp crystals of pyrite and some epidote are also developed in this rock.

Tuffs of the acid rocks.—Closely allied to these schistose porphyries which occur in dikes are certain banded acid rocks whose most important exposures are along the southern edge of the northern Marquette greenstone area, near the junction of this with the fissile argillaceous shales of the "Eureka series." These are hard, compact, fine grained, but decidedly schistose beds, locally known as novaculite. Indeed, these rocks have been worked to a limited extent as whetstone, whence the name of the small creek flowing through the southern part of Marquette.

The color of these so-called novaculites is sometimes reddish, sometimes pale greenish or yellowish. They are very frequently striped with different shades. Under the microscope they closely resemble the groundmass of the quartz porphyries described in the last section. No porphyritic crystals, however, are ever observed, and the structure is too fine grained to appear schistose in a thin section.

Three essentially identical sections of these rocks were studied from specimens collected at three of the most typical exposures.

No. 11627 is from near Burgess's saw-mill, at the east end of Lake street, Marquette. It has a reddish color produced by an abundance of iron hydroxide scales. The grain is for the most part quite regular, although larger and angular quartz fragments are occasionally seen.

No. 11684 was taken from the glaciated exposure of the novaculites, occurring at the west end of Ridge street, Marquette. A fresh fracture in this rock shows a light gray color. It is parted by intersecting joint systems into sharp rhomboidal prisms which strike slightly south of west. Under the microscope this rock appears as a fine, even mixture of quartz grains and sericite flakes.

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No. 11676 was collected at the south end of the "Brook section," near Steinbrecher's house. (B of map, Plate VII.) It is quite similar to the others, but it is much seamed with infiltrated quartz, small veins of which appear in the microscopic section.

The regular banding of these anomalous acid rocks, as well as their interstratification with and gradual passage into the similarly banded greenstone schists, will not admit of the supposition that they were ever eruptive masses, however much we may imagine these to have been metamorphosed. On the other hand, their similarity, in both composition and structure, to the groundmass of the quartz porphyries, is too striking to be overlooked.

Apparently only two hypotheses are altogether reconcilable with the observed facts: First, that the rocks are true sediments, like those of the Eureka series, along whose northern edge they lie, which may have been largely derived from disintegrated quartz porphyry material; or second, that they are consolidated acid tuffs which accompanied the eruptions of the porphyries, in the same manner that some of the greenstone schists represent the fragmental diabase material.

Another possible supposition is that these compact, hornstone-like rocks resulted from the contact-metamorphism of preexistent sediments by the diabase eruptions. Such an effect has been extensively produced by the Hartz Mountain diabase, as has been shown by the work of Lossen and others. The resultant rock is known as *adinole*, but it differs essentially from the Marquette novaculite in a constant and high percentage of soda, due to the presence of albite. This, as may be seen from the following analysis, is absent from the Marquette rock. We further have no evidence of the existence of sediments when the greenstones were produced, as all the Huronian beds are younger.

Of the two first mentioned hypotheses, the second is the more probable, first, because of the very constant character of these banded acid rocks, and second, because of their almost exact identity in chemical composition with the massive acid eruptives. The following chemical analysis of specimen No. 11684, from the west end of Ridge street, Marquette, was made by Mr. W. F. Hillebrand:

Silica (SiO_2)	76.99	Potash (K_2O)	3.65
Alumina (Al_2O_3)	13.92	Soda (Na_2O)	0.56
Ferric oxide (Fe_2O_3)	0.45	Lithia (Li_2O)	Trace.
Ferrous oxide (FeO)	0.77	Water (H_2O)	2.35
Manganous oxide (MnO)	Trace.	Phosphorous pentoxide (P_2O_5)	Trace.
Lime (CaO)	0.32		
Magnesia (MgO)	1.12	Total	100.13

It will be seen that this is the composition of an aggregate of quartz and sericite, as the microscope shows our novaculite to be. The sericite is in all probability the result of the alteration of original orthoclase.

The occurrence of similar tuff deposits in connection with eruptive quartz porphyries is well known in Europe, especially in the German

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dyas. They have been carefully studied and described in Saxony,[1] the Vosges Mountains,[2] the Black Forest,[3] and Odenwald.[4] The writer can speak from a very considerable personal acquaintance with the Black Forest and Odenwald tuffs, of their very close resemblance to the Marquette novaculites.

But perhaps the closest analogues of the Marquette tuffs are to be found among those described by Dr. Archibald Geikie, from St. David's, in Wales,[5] a region which, as we shall see in the sequel, presents many points of resemblance to the Marquette district. The analysis of one of them, hereafter quoted (V), agrees very closely with that of our novaculite. Dr. Geikie finds that these acid tuffs accompanied superficial eruptions of quartz porphyries, which were intimately associated with more abundant and contemporaneous extrusions of diabase and diabase tuffs. The acid tuffs have been derived from true fine grained felsites. Some of them are conglomeratic (agglomerates); some of them fine ashy material, which has become consolidated into a sericitic schist. There are various intermediate varieties between the acid and basic types, due to the mingling in different proportions of the two kinds of debris.

Mr. J. S. Diller[6] has also shown that the felsitic rock from Breakheart Hill, near Saugus, Massachusetts, is a silicified quartz porphyry tuff; and from the sharply angular shape of the quartz fragments, of which it is now composed, he concludes that these are pseudomorphs after fragments of an acid glass originally deposited as a volcanic ash.

The following analyses of well characterized acid tuffs from European localities are here quoted on account of their similarity to the Marquette novaculite:

	I.	II.	III.	IV.	V.
Silica (SiO_2)	76.37	79.73	82.47	84.12	80.59
Alumina (Al_2O_3)	13.94	11.34	9.55	9.38	11.29
Ferric oxide (Fe_2O_3)	3.18	0.99	0.43	1.78	0.28
Ferrous oxide (FeO)			0.57		*1.41
Lime (CaO)	.....	.....	0.53	0.08	0.52
Magnesia (MgO)	.....	0.27	trace ...	0.01	0.95
Potash (K_2O)	4.39	3.81	4.69	0.85	2.98
Soda (Na_2O)	1.07	0.17	0.58	0.25	0.72
Water (H_2O)	1.58	2.12	1.18	3.68	†1.96
Total	100.53	98.43	100.00	100.15	100.70

* Manganous oxide trace. † Loss on ignition and water.

[1] C. F. Naumann: Geognosie, 2d ed., vol. 1, p. 671, 1858. Also Erläuterungen zur geol. Specialkarte des kön. Sachsens, Sect. Frohburg (59), Colditz (44), Döbeln (46), Leisnig-Lausigk (43), and Rochlitz (60).

[2] D. Gerhard: Geognostisch-petrographische Mittheilungen aus dem Gebweiler-Thal, 1880. (Cf. Neues Jahrbuch für Mineral., 1881, vol. 1, Referate p. 374).

[3] G. H. Williams: Neues Jahrbuch für Mineral., Beilage-Band 2, pp. 626–634.

[4] Benecke and Cohen: Geogn. Beschr. d. Umgegend von Heidelberg, 1881. pp. 221–235.

[5] On the supposed pre-Cambrian rocks of St. David's. Quart. Jour. Geol. Soc. London, vol. 39, pp. 298–301, 1883.

[6] The felsites and their associated rocks north of Boston. Proc. Bost. Soc. Nat. Hist., vol. 20, pp. 355–368; Bull. Mus. Comp. Zool., Harvard Coll. Whole Series, vol. 7, pp. 165–180; also Science, 1884. vol. 3, p. 653.

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I. Thonstein (tuff) from Zeisigwald, near Chemnitz, Saxony.[1]
II. Same.[2]
III. Silicified tuff, Oelberg, near Schriesheim, Odenwald.[3]
IV. Silicified tuff, Kesselberg, near Triberg, Black Forest.[4]
V. Felsitic tuff breccia, Clegyr Hill, St. David's, Wales.[5]

If, then, these banded acid rocks occurring near Marquette, as seems most probable, really do represent solidified tuff material of the quartz porphyries, we might expect to find transitional forms, grading into the banded green schists. These do appear to exist, and indicate that some, at least, of the eruptions of both acid and basic rocks were nearly contemporaneous.

BANDED GREENSTONE SCHISTS.

The banded greenstone schists which form the prevailing rock over the northern portion of the Marquette area have been regarded by all geologists who have ever studied them as originally sedimentary deposits, and a repeated examination of them in the field seems incapable of leading to any other conclusion. They are everywhere stratified with the greatest regularity in bands of lighter and darker shades of green. This structure is to be most advantageously seen in the woods just north of Marquette and near Lighthouse Point. Here glaciated areas of considerable extent often show a finely ribboned appearance, looking as though the sharp, parallel lines had been drawn with a ruler. The alternation in the color and composition of the layers is so frequent and so constant, and their parallelism to the east and west strike of all the rocks of this neighborhood is so exact that no hypothesis of their originally massive character will satisfactorily account for the observed facts.

On the other hand, the chemical and the microscopical characters of these schists agree closely with those of associated massive greenstones which are known to have been derived by the alteration of basic eruptive rocks. Both are composed of fibrous green hornblende, quartz, epidote, zoisite, and chlorite. There must, therefore, have been a close similarity in the original composition of these two classes of rocks, in spite of the wide difference in their structure.

Prof. M. E. Wadsworth, who has ably advocated the eruptive origin of many of the rocks occurring near Marquette, regards these banded schists as undoubtedly of sedimentary origin. He says:[6]

The schist from the same specimen (45) is composed of quartz, argillaceous material, chlorite, hornblende, magnetite, "leucoxene," and a little augite. It would seem that this had been formed from detrital material of the same nature as the dikes (basaltic). The close resemblance of the "diorite" and schist in mineralogical characters, but not in structure, is shown in another section containing the junction of the two rocks (48).

[1] Neues Jahrbuch für Mineral., 1864.
[2] Ibid., 1859.
[3] Die zur Dyas gehörigen Gesteine des südlichen Odenwaldes, von E. Cohen, 1871, p. 57.
[4] Neues Jahrbuch für Mineral., Beilage-Band 2, p. 630.
[5] Quart. Jour. Geol. Soc. London, vol. 39, 1883, p. 297.
[6] Notes on the Iron and Copper Districts of Lake Superior. Bull. Mus. Comp. Zool., Harvard Coll., Whole Series, vol. 7, Geol. Series, vol. 1, p. 37.

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Specimes of these banded greenstone schists which were collected from different localities within the northern Marquette area, although they are macroscopically nearly identical, present a great variety in their microscopical structure.

Nos. 11618 and 11619, from Lighthouse Point, Marquette, are comparatively coarse grained rocks composed largely of a green fibrous hornblende. The structure of this mineral, especially in No. 11619, is unusual. What at first glance looks like a confused mass of irregular and ragged hornblende areas, when more carefully examined, is found to consist of more or less radiating bundles of hornblende fibers, resembling sheaves. The center of these bundles is their most compact portion. Here the hornblende substance is often continuous and homogeneous, but toward the two ends of the mass it appears to be frayed out into separate fibers. These are so regularly divergent in their arrangement as to produce a black brush which sweeps across them as the stage of the microscope is revolved between crossed Nicol prisms. This peculiar, sheaf-like grouping of the hornblende is shown in Pl. XVI, Fig. 1. It is very similar to that described by de la Vallée-Poussin and Renard in an amphibolite occurring near Laifour, in the valley of the Meuse,[1] and by Renard in the metamorphosed Devonian slates of Bastogne in the Ardennes Mountains.[2] Though it can still be traced in specimen No. 11618, this structure is by no means as distinct as in the case just described.

The groundmass in which this hornblende lies is a finely granular aggregate of albite, or quartz and albite grains. In it occur some chlorite, epidote, or zoisite in good sized individuals, and, at least in No. 11619, some small ilmenite particles, surrounded by a highly refractive leucoxene border. There is comparatively little groundmass in either of these specimens, but of the two No. 11618 contains the more.

Nos. 11730, from the western part of Marquette, between Michigan and Ohio streets, and 11734, from the corner of Front and Ohio streets, are both banded greenstones of the same type as the specimens last described. The former contains less hornblende, though this mineral, is, nevertheless, abundant in the same sheaf-like bundles as before. The groundmass is a fine grained albite mosaic, which contains some quartz and some epidote. The latter specimen, No. 11734, is largely composed of an unusually dark green and pleochroic hornblende, in confused ragged and fibrous groups. Along certain lines, where this component is less abundant, the rock assumes a lighter shade. The albite mosaic is present, but not to the exclusion of areas of gray saussurite, which sometimes show indications of a lath-like form, like that of the diabase feldspars. Narrow seams filled with epidote, or an aggregate of albite and epidote, traverse this rock parallel to its banding. Ilmenite grains, with their rims of leucoxene, occur in each of these specimens.

[1] Mém. sur les char. min. et strat. des roches dites plutoniennes, etc., Brussels, 1876, p. 252, Pl. V, Fig. 25.

[2] Les roches grénatifères et amphiboliques de la région de Bastogne. Bull. Mus. roy. d'hist. nat. de Belgique, 1882.

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There is nothing in the microscopical structure of these slides to suggest a massive eruptive rock; on the contrary, the two instances cited, where a similar sheaf-like hornblende has before been noticed, are cases of supposed metamorphosed tuffs.

No. 11630, from the quarry on Lighthouse Point (A of map, Pl. VII) is also largely composed of hornblende in pale green, ragged-looking individuals, but without any of the sheaf-like structure. Amid the hornblende a clear transparent feldspar, evidently albite, has been abundantly developed in good-sized grains, which show a sharp twinning striation. The gradation of this well characterized albite into the granular mosaic lends additional force to the supposition that this also is composed of the same mineral, as, indeed, Lossen has shown to be the case in many of the regionally metamorphosed diabases of the eastern Hartz.[1]

Nos. 11631 and 11637 are other specimens of the banded greenstone schists from the same quarry as the last on Lighthouse Point. The former is, perhaps, the most typical, although an abundance of calcite shows that it is much weathered. Its alternating light and dark green bands are due to the fact that hornblende is still present in the latter, while its place is supplied in the lighter colored bands by a pale chlorite and epidote. An opaque iron oxide, often surrounded by a leucoxene rim, is found in small particles scattered through this rock, as is also a little biotite. The second of the above mentioned specimens, No. 11637, which was taken from just beside the great dike, shows what the last described rock was when it was in a fresher condition. The calcite is here absent, and the rock is, for the most part, a mass of ragged and raveled hornblende. Among this is scattered some clear, transparent feldspar (probably albite) and zoisite, or epidote, which occurs in irregular crystalloids, arranged in long, parallel lines. The iron mineral and biotite are present as before.

No. 11623, found beside the great dike on Lighthouse Point, is only a confused aggregate of very pale and very fibrous hornblende needles with calcite. Lighter bands are occasioned in this rock by a preponderance of calcite and chlorite over the hornblende.

No. 11626 is a gray schistose rock from the exposure near Burgess's saw-mill, on Lake street, Marquette. It is full of calcite, which is arranged in bands along with a very finely granular mosaic. Hardly any hornblende is visible in this specimen, but veins of epidote and some chlorite occur in it.

Along the deep north and south exposure of the greenstone schists which has been described as the Brook section, these banded greenstones are also very admirably displayed. For the most part they are quite like those occurring in the neighborhood of Marquette. In one particular, however, some of them present an unusual feature which it is not altogether easy to explain. This consists in the presence of len-

[1] Zeitschr. Deutsch. geol. Gesell., vol. 24, 1872, p. 730. Jahrbuch preuss. geol. Landesanstalt für 1883, p. 640; ibid., für 1884, p. 528. Erläut. zur geol. Specialkarte von Pr., Blatt Wippra, Berlin, 1883.

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ticular masses of a white feldspathic substance, which are so elongated in the direction of the bedding that while they generally present a lens-shaped form, their cross-section is nearly circular. The size of these lenses, which externally resemble what the Germans call "Augen" or eyes, is extremely variable. Some are smaller than peas, while others are more than two inches in length. The extent also to which they are elongated differs very much in different cases. Some are represented only by narrow white lines which are occasionally thickened or swelled out into oval spots. Between these and such as vary comparatively little from a spherical form we may find all intermediate stages.

These white lenses are by no means universally distributed through the green-schists of the Brook section; on the contrary they occur only rarely in bands which transverse the greenstones parallel to their bedding. One of these bands consisted of only a few rows of large, oval masses, exactly resembling rounded pebbles, but in spite of its narrowness it could be traced for a considerable distance.

The white color of these lenses or "Augen" presents a decided contrast to the dark green of the inclosing schists. Their outline, too, is quite sharp, and yet, upon a close examination, they are seen to pass gradually into the substance of the surrounding rock. What their origin was, whether they were inclusions much flattened by subsequent pressure, or secretions of the rock itself, or infiltrations, it now seems difficult, if not impossible, to decide.

Sections 11703 to 11705*a*, show the microscopic composition and structure of these lenticular masses as well as their relation to the inclosing rock. This latter is in all cases a typical hornblende schist or amphibolite. It is composed of small, compact needles of strongly pleochroic, green hornblende, colorless grains of feldspar and probably quartz, and the minute, highly refractive epidote particles so characteristic of the crystalline schists. The feldspar is very fresh and free from inclusions, as though it were the product of a new crystallization. It rarely possesses an albite or microcline twinning structure, but for the most part it is so homogeneous and limpid that it closely resembles quartz. Lossen has called particular attention to the difficulty of distinguishing a mosaic of secondary albite from quartz under the microscope,[1] and it is very possible that quartz grains are actually present in this rock, although in certain favorable cases a biaxial character was substantiated.

No. 11703 is cut in the direction of the bedding and shows the hornblende in strictly parallel arrangement. Its feldspar "Augen" are very much elongated, while in No. 11705, which is cut nearly perpendicular to the bedding, they are as broad as they are long. This substance was undoubtedly once some triclinic feldspar, but this has been changed to saussurite which now consists of epidote and sericite imbedded in a

[1] Zeitschr. Deutsch. geol. Gesell., vol. 31, 1879, p. 441, et seq. Jahrbuch preuss. geol. Landesanstalt für 1884, pp. 528, 544, Pl. XXIX, fig. 4.

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new crystallization of albite. They contain no hornblende, but there seems to be a condensation of this mineral in the schist around their edge and enough of it penetrates for a distance into their substance to form a gradual transition rather than a sharp line of contact between them and the inclosing rock.

The composition of these "Augen" is not in every instance the same, although they all appear to have been derived from some form of feldspar. In No. 11704 they are composed wholly of epidote, while in No. 11705*a* the original feldspar was more acid and sericite has been produced almost to the exclusion of epidote.

Other of the banded greenstones collected along the Brook section are quite devoid of the white "Augen" and agree closely with the rocks around Marquette.

Nos. 11706, 11713, and 11718 are essentially hornblende rocks, containing some altered feldspar and some quartz. They are plainly banded, the alternate layers differing in both color and composition.

No. 11671, from an exposure very near the center of section 17, consists of sharp epidote needles and a little quartz, imbedded in a confused mass of pale green, fibrous hornblende.

Nos. 11610, 11611, and 11667, from near the powder mill on Dead River, are all schistose greenstones in a much altered condition consisting now of chlorite, quartz, and carbonates.

As has been already remarked, the structure of these greenstone-schists is such as to necessitate a belief in the original nature of their stratification; while, on the other hand, their chemical as well as their mineralogical composition renders it impossible to separate them from the massive and highly altered greenstones (uralite diabases, etc.), with which they are most intimately associated. Their parallel banding indicates a fragmental, but their chemical and their mineral composition indicate an igneous origin. The only satisfactory reconciliation of these opposite sets of characters is to be found in that group of rocks intermediate between sediments and lavas, known as volcanic tuffs.

In the opinion of the writer, then, the banded greenstone schists of the northern Marquette area are to be regarded as consolidated and highly metamorphosed *diabase tuffs*. These are intimately associated with numerous contemporaneous flows of diabase and quartz porphyry, together with tuffs of the latter rock; while all have been broken through by much younger dikes, both basic and acidic.

From the preceding petrographical descriptions it will be seen how great is the similarity between the banded greenstones of Marquette and the older massive diabases. Mineralogically, they are now identical, but the fine parallel banding of the former necessitates the assumption that their origin differed from that of the eruptives.

In a former paper[1] the writer has maintained that two geological

[1] Bull. U. S. Geol. Survey, No. 28, p. 1.

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masses as different in their structure and origin as a clay-bank and a lava-stream, *if they possessed the same chemical composition to start with*, when subjected for a long period to exactly the same physical conditions, would result in the same products. This is, of course, true only when these conditions allow of profound metasomatic and structural changes. On the other hand, when we find two intimately associated rocks which for a long time have been subjected to exactly the same conditions, but which still bear evidence of dissimilar origin, in spite of practical identity of mineral and chemical composition, we may safely consider them as originally of the same, or of similar chemical composition. Now, it is difficult to imagine any stratified sediments of the composition of diabase, except diabase ashes; nor could these have undergone transportation by water without suffering important chemical changes. We therefore conclude that the banded schists represent volcanic debris deposited at or near the point of its origin.

In order to obtain a clear idea of just how these ancient and much disguised tuffs acquired their present form and apparently dual character, it will be advantageous to ascertain what is known of analagous formations of comparatively recent date. Capt. C. E. Dutton's descriptions[1] of the fragmental rocks accompanying the Tertiary eruptives of the high plateaus of Utah, are well suited to this purpose. He says, in speaking of the extent of these deposits:[2]

Some of the most interesting lithological problems presented by the volcanic products of the high plateaus are those relating to the origin and development of what may be termed the clastic igneous rocks, or rocks apparently composed of fragmental materials of igneous or volcanic origin, but now stratified either as so-called tufaceous deposits or as conglomerates. These are exceedingly abundant in all of the great volcanic districts of the world, and often enormously voluminous. How those of the high plateaus would compare, in respect to magnitude, with those of other regions, I do not accurately know, but absolutely their bulk is a source of utter astonishment. They cover nearly 2,000 square miles of area, and their thickness ranges from a few hundred feet to nearly 2,500 feet, the average being probably more than 1,200 feet. Lavas are frequently intercalated, but much more frequently no intercalary lavas are seen, and in general they seldom for any large proportion of the entire bulk when they occur in conjunction with the clastic masses.

Again, in speaking of the peculiar liability of such deposits to metamorphism, the same writer says:[3]

A very striking characteristic of these clastic volcanic rocks, both the tufas and the conglomerates, is their great susceptibility to metamorphism. Not only have the beds in many localities been thoroughly consolidated, but they have undergone crystallization. Those tufas and conglomerates which are of older date, and which have been buried beneath more recent accumulations to considerable depths, rarely fail to show conspicuous traces of alteration, and in many cases have been so profoundly modified that for a considerable time there was doubt as to their true character. The general tendency of this process is to convert the fragmental strata into rocks having a petrographic facies and texture very closely resembling certain groups of igneous rocks. When we examine the rocks in situ no doubt can exist for a moment that

[1] Report on the Geology of the High Plateaus of Utah. By C. E. Dutton; Washington, 1880.
[2] Ibid., p. 69.
[3] Ibid., pp. 79, 80.

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they are water-laid strata. The hand-specimens taken from the beds, which are extremely metamorphosed, might readily pass, even upon close inspection, for pieces of massive eruptive rocks were it not that the original fragments are still distinguishable, partly by slight differences of color, partly by slight differences in the degree of coarseness of texture. But the matrix has become very similar to the included fragments, holding the same kinds of crystals, and under the microscope it shows a groundmass of the same texture and composition. * * *

I see nothing at all incredible in the idea of metamorphism producing rocks so closely resembling some eruptive rocks that they can not be petrographically distinguished from them. It seems rather that we ought to anticipate just such a result from the alteration and consolidation of pyroclastic strata. The materials which compose them consisted originally of disintegrated feldspar, pyroxene, and the matter which constitutes the amorphous base of all eruptive rocks.

We are thus enabled to see that there is, at least, no geological difficulty in the explanation here offered of the origin and nature of the banded green-schists at Marquette. On the high plateaus of Utah, which form one of many similar districts, conditions are plainly seen to have prevailed quite similar to those here assumed for the more ancient rocks of Lake Superior; and yet the metamorphism which has taken place in the ancient Archean deposits is hardly greater than that described by Captain Dutton in the tertiary tuffs.

The most generally accepted type of diabase tuffs is the German "Schalstein;" but, as Rosenbusch well remarks,[1] in the course of many years so many totally different rocks, with only the most superficial resemblance to each other, have been described under this designation, that there is now no definite meaning whatever which can be attached to this term. The schalsteins are for the most part, green or greenish in color, earthy and schistose; but among them have been included altered and foliated diabases on the one hand, and true sediments on the other, while some of them are undoubtedly true diabase tuffs. In Germany their distribution is very wide in Nassau, Saxony, and Bavaria.

The microscopic sections of German Schalsteins accessible to me for comparison were those in the Stürtz collection of typical rocks belonging to the petrographical laboratory of the Johns Hopkins University. They are from the localities of Rübeland in the Hartz Mountains, and Diez, Baldinnstein, Dillenburg, and Weilburg in Nassau. In spite of extreme alteration, resulting in several cases in the survival of only chlorite, calcite, and iron oxide, it can be distinctly seen that the specimens were originally totally different. The rocks from Diez, Dillenburg, and two out of the three labeled Weilburg, are only very amygdaloidal diabases. The structure in the base is well preserved, while the amygdules are filled with calcite surrounded by a rim of chlorite. The rock from Rübeland is apparently of the same nature, but the original structure has now disappeared. In the specimen from Baldinnstein and in one from Weilburg there is no indication of diabase structure, but there is a spheroidal aggregation resembling that seen in palagonite.

[1] Mikros. Physiog., 2d ed., vol. 2, p. 245.

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The most extended descriptions of these rocks have been given by Gümbel, who has treated the schalsteins of the Fichtelgebirge in Bavaria in a most careful manner.[1] Rothpletz has described the tuffs and agglomerates associated with the Silurian diabases in Saxony.[2] In Great Britain the ancient volcanic areas of Cornwall and St. David's in Wales show the closest similarity, both in the character of their rocks and in certain features of their structure to the Marquette region. The slaty blue "elvans" of the former district were regarded by De la Beche as altered ash-beds.[3] J. Arthur Phillips arrived at the same conclusion.[4] He says:

> The Cornish rocks afford numerous examples of ancient lava flows so interbedded with slates and schists of the district as to lead irresistibly to the conclusion that they are contemporaneous ingeous deposits.

Also again:[5]

> The slaty blue elvans found between St. Erth and St. Stephens (in Bramwell) have a chemical composition identical with that of the altered dolerites, and may be, as was formerly suggested, highly metamorphosed ash-beds.

The basic tuffs, like the acid ones, occurring at St. David's have been described by Dr. A. Geikie.[6] He finds that all varieties of texture can be traced, from large grained breccias to fine schistose mudstones. The finer material includes angular, subangular, and rounded blocks or lapilli, consisting not alone of diabase, but also of the more acid felsitic rocks. These are true agglomerates, and their striking resemblance to certain other of the schistose greenstones of the Marquette belt will be alluded to in the sequel.

The eruptive rocks which Dr. Hans Reusch has recently studied in the regionally or dynamically metamorphosed district on the west coast of Norway, present a close resemblance to those occurring near Marquette.[7] He finds diorites, in part very schistose, which have originated through the metamorphism (uralitization and epidotization) of ancient

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[1] Geognostische Beschreibung des Fichtelgebirges, mit dem Frankenwald und dem westlichen Vorlande, Gotha, 1879, pp. 222 et seq.

[2] Erl. zur geol. Specialk. Sachsens, Sect. Frankenberg-Hainichen (78), pp. 16 and 21; Sect. Schellenberg-Flöha (97), p. 65.

[3] Geological Observer.

[4] Quart. Jour. Geol. Soc. London, vol. 34, p. 493.

[5] Ibid, p. 495.

[6] Quart. Jour. Geol. Soc. London, vol. 39, p. 297, 1883.

[7] Geologische Beobachtungen in einem regional-metamorphosirten Gebiet am Hardangerfjord in Norwegen, Neues Jahrbuch für Mineral., Beilage-Band 5, pp. 52–67. On pages 54, 55 the author says: Nicht selten zeigt das dioritische Gestein einen schichtenweisen Wechsel von verschiedenen Varietäten. In diesem Falle bin ich geneigt, anzunehmen, dass das ursprüngliche Gestein nach Art der Tuffe gebildet wurde. Dies geschichtete dioritische Gestein bildet einen Uebergang zu den grünlichen feinkörnigen oder dichten, geschichteten, mehr oder weniger schieferigen Gesteinsarten, welche die Hauptmasse von dem ausmachen, was ich für basische Tuffe halte. Diese Gesteine führen als wesentliche Bestandtheile Hornblende, Chlorit und Epidot, daneben gern reichlich Carbonspath. Sie entsprechen einigermassen den Schalsteinen der deutschen Petrographen. Eingelagert kommen Massen vor, die man am ehesten für geflossene Ströme halten muss. Einige sind wohl auch intrusive Gänge. Uebrigens ist es hier, wie anderswo unter ähnlichen Verhältnissen, oft schwierig zu unterscheiden was massig erstarrt und was klastische Bildung ist. For the detailed descriptions of these rocks by Dr. Reusch, see "Bommelöen og Karmöen," Christiania, 1888 (in Danish), p. 112, and the appended English summary of contents, p. 402.

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gabbros. These are most intimately associated with granites and quartz porphyries, while both acid and basic rocks are accompanied by abundant tuff deposits.

In America hardly anything reliable has been published on basic tuffs. Edward Hitchcock speaks of diabase tuffs in the trias of Massachusetts, but gives nothing specific respecting their nature.[1] References to this class of deposits are scattered through the writings of some of the Canadian geologists, especially in the recent report of Mr. A. C. Lawson on the Lake of the Woods region.[2]

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[1] Geology of Massachusetts, 4°, 1841, p. 648.

[2] Geol. and Nat. Hist. Survey Canada, Ann. Rept. for 1885, Rept. CC., 1886.

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CHAPTER V.

GREENSTONE BELTS OF THE MARQUETTE DISTRICT—Continued.

ROCKS OF THE SOUTHERN PORTION OF THE MARQUETTE AREA.

On the south side of the narrow band of Huronian slates which has been designated as the "Eureka Series," the greenstones of the Marquette area present a decided contrast to those which have been described in the previous section as occurring on its north side. They are, for the most part, massive, pale green in color, and apparently homogeneous in structure. Only in rare instances can individual minerals be detected with the unaided eye. A schistose structure is not uncommon in these rocks, but it is evidently a pressure foliation, while the parallel banding or striping, so frequent in the greenstones of the northern area, is altogether absent. A study of these pale green aphanitic greenstones seems to indicate that they were not originally to any great extent tuff deposits, but massive flows of diabase, which have since suffered profound chemical and structural change in consequence of having been subjected to intense dynamical action.

In addition to their foliation, they are fractured and brecciated in various degrees, and often exhibit a curious spheroidal or lenticular parting, for which no perfectly satisfactory explanation has been found.

The monotony of these prevailing aphanitic greenstones is interrupted by bands of more coarsely crystalline and less altered rocks, which represent basic dikes of more recent origin.

THE APHANITIC GREENSTONES.

The general character of these widely distributed rocks as seen under the microscope, is shown in Pl. X, fig. 2, drawn from a specimen collected near the town of Negaunee, where this type is developed even better than near Marquette. In the mass which appears to the unaided eye as quite homogeneous, the microscope discloses long, almost acicular feldspar crystals, embedded in a confused aggregate of hornblende needles, chlorite scales, epidote, quartz, calcite, and cloudy spots, probably derived from leucoxene. The feldspar in these rocks is, as a rule, fresh, and their twinning lamellæ are still distinctly visible. Some of the more acicular crystals seem divided at the ends, as is so often the case in semi-vitreous surface rocks whose feldspar microliths are not completely formed. Indeed, in many of their characters, these aphanitic greenstones strongly resemble porphyrites or melaphyres

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whose glassy base has been completely transformed into an aggregate of secondary products. Their structure, imperfectly preserved as it is, strongly indicates a superficial origin.

As typical representatives of these homogeneous pale green rocks may be mentioned: No. 11638, from the mouth of Whetstone Brook, just south of Marquette; Nos. 11725 and 11726, from the summit of the hill immediately south of the last locality; No. 11694, collected about an eighth of a mile south of the State road on the line between the southeast and southwest quarters of Sec. 27, T. 48 N., R. 25 W.; and No. 11721, from south of the township road, on the line between Secs. 27 and 28, T. 48 N., R. 25 W.

These aphanitic greenstones appear to have been particularly sensitive to dynamic action. We find locally developed in them every degree of pressure foliation from a coarse, slickensided breccia to a chloritic slate. The cleavage, however, is developed parallel to a line rather than parallel to a plane, as is the case with a true bedding. There is a tendency to break into rhomboidal prisms or along almost any plane which is parallel to the average direction of dip.

No. 11696 is a much gashed and brecciated greenstone which adjoins on the north an uralite diabase dike, No. 11695 (see p. 169). It is both schistose and chloritic, but its microscopical structure shows plainly that it was once a diabase, and that its present character is due entirely to the action of some great mechanical force. The typical ophitic structure or irregular network of lath-shaped feldspar crystals is still readily discernible. The mechanical action seems to have been rather a stretching than a compression. The feldspar crystals, which are considerably altered, are broken and the fragments pulled apart. The secondary chlorite, so common in all stretched rocks (cf. Pl. XI, fig. 2), is here abundant in the numerous longitudinal cracks, which traverse the rock irrespective of its component minerals. This is always arranged with its scales or fibers perpendicular to the walls of the fissure.

In addition to such brecciated rocks as the last specimen, very perfectly schistose varieties of these aphanitic greenstones are common in the southern part of the Marquette area, their strike conforming to that of all the other rocks of this region. These are typically exposed at the mouth of Whetstone Brook (Nos. 11639 to 11643); in the railroad cutting just west of it (No. 11645); on the high hill still farther westward (No. 11726); and in the Duluth, South Shore and Atlantic Railroad cutting just north of the Marquette sandstone quarries (No. 11691).

For the most part, these rocks are a fine chloritic mass, which, under the microscope, shows a pronounced schistose structure, but only rarely any certain indications of eruptive origin. Very faint but unmistakable traces of the ophitic structure are nevertheless sometimes visible even in these rocks, as, for instance, in No. 11726, which was entered in the field notes as a "slaty band traversing the massive greenstones above Whetstone Brook."

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The history of these schistose greenstones must be deciphered with the conjoint evidence afforded by the microscope and a study of their relations in the field. The occasional survival of the characteristic diabase structure even in some of the more foliated forms, taken in connection with their evident identity with and gradual transition into the massive varieties, appears to be sufficient proof that, with the exception of certain unimportant tuff deposits, these green schists have been derived from basic eruptives through the agency of intense mechanical and chemical action.

The closest analogy to the rocks of the southern Marquette greenstone area is to be found in the metamorphosed diabases of the eastern Hartz. These rocks have been minutely studied and for the first time successfully deciphered by K. A. Lossen, of Berlin. His descriptions could be applied almost verbatim to the Marquette greenstones; and each of these two similar areas can but have additional light thrown upon its interpretation by the facts afforded by the other.[1] Lossen distinguishes between the coarse grained or granular (körnig) and the fine grained (aphanitisch) diabase, as has been done in the area here under discussion. He finds that both rocks, but especially the aphanitic type, are very sensitive to dynamic action, and that in the process of mountain making they have been to a large extent passively metamorphosed and converted into breccias, "Flaser" diabase and green schists. The last named "grüne Schiefer" are of particular interest to us on account of their resemblance to the schistose rocks of the southern Marquette area. In the Hartz they make a conformable member of the Wieder schists (hercynian) which are of very considerable extent and are always associated with the aphanitic diabase. The minute and careful studies of Lossen have led him to the conclusion that these schists are not in any way sediments nor even diabase tuffs ("Schalsteine"), but molecularly metamorphosed eruptive rocks, of a fine grained diabase type.[2] The more massive rocks are considered to represent old lava flows which occurred while the accompanying sediments were being deposited, and the idea that the green schists of the Wieder horizon were once also massive diabases, is based both upon the field relations of these rocks and more especially upon the frequent remains of the diabase structure which they still contain.

The published descriptions of many other green schist areas in Europe—notably in Bavaria, Saxony and the Taunus—show that they possess a strong resemblance to those of Michigan and the Eastern Hartz, and it is not improbable that they also may have had a similar origin.

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[1] The descriptions of Lossen are contained in the explanations to the special geological map of Prussia and Thuringia (Erläuterungen zur geologischen Specialkarte von Preussen und den thüringischen Staaten) sheets Pansfelde (1882), and Wippra (1883).

[2] "Die mikroskopische Untersuchung characteristischer Vorkommen dieser typischen Diabasaphaniten vergesellschafteten grünen Schiefer hat ergeben, dass sie, wenn nicht insgesammt, doch grossentheils als *unter Druckschieferung molecular umgewandelte Diabase* aufzufassen sind." Ibid., Bl. Wippra, p. 27; (cf. also p. 46 and Bl. Pansfelde, p. 52).

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A noteworthy feature of the aphanitic greenstones and greenstone schists of the southern Marquette area, and one which is exhibited in a still more marked degree by the similar rocks occurring near the town of Negaunee (see the following section), is their frequent division into spheroidal, ovoid, lenticular or more irregularly shaped masses. These differ very much in size, as well as form, and often show a tendency to fit together like stones in a mosaic, although they are always separated by interlacing bands of a softer, more schistose and generally darker material. These anastomosing bands seem to wind about the harder and more massive cores, becoming thinner or thicker according as the masses approach each other more closely, or are more widely separated by the rounding off of their corners. This peculiar structure, which appears to be only local in its development, may be seen at the mouth of Whetstone Brook in Marquette, near Baldwin's kilns, near Negaunee (NE ¼ of NW ¼ of Sec. 28 W., T. 48 N., R. 26 W.), and on the south side of the Carp River along the logging road leading northward from the east end of Teal Lake. The accompanying diagram (Fig. 26), drawn from the last named exposure, illustrates the general character of this structure.

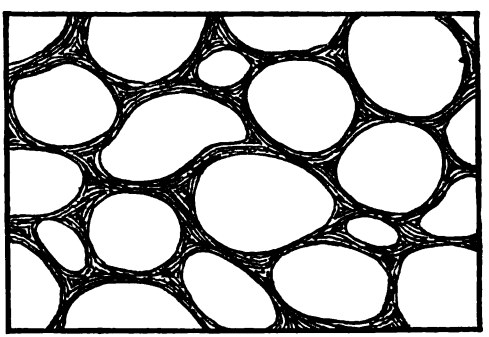

FIG. 26.—Diagram to illustrate spheroidal parting in aphanitic greenstone. Carp River. Scale, 3 feet to the inch.

The cores generally seem to be quite massive, but in some cases they have a latent foliation which is developed by weathering. Where the rock has become decidedly schistose, as was observed in one part of the Carp River exposure, these cores are pulled out into long interlocking lenses, which have their longest axes parallel to the foliation. (See Fig. 27, p. 177.)

Such a structure as that above described appears to be not uncommon in the greenstones and greenstone schists of the Northwest. It is well known to the Canadian geologists, who have designated the rocks exhibiting it as "concretionary traps." It is described by Dr. Andrew C. Lawson, in his report on the Lake of the Woods, in the following terms:

This structure consists of the rock being divided into more or less irregularly spherical or ovoid masses, varying in diameter from 2 to 3 inches to as many feet. These ovoid masses are not in close contact, but are separated from one another by an in-

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terstitial material. The concretionary masses are at their points of nearest approximation to each other, generally about half an inch or an inch apart, no matter what may be their size, so that when the ovoid masses are large, the interstitial material appears in section as thin, anastomosing sheets, in which is developed a schistosity parallel to the outlines of the ovoid masses they inclose. The interstitial filling is generally of a darker color, more chloritic, softer, and of a finer, more homogeneous texture than the ovoid masses, and weathers out, often leaving the latter, in sections afforded by glaciated surfaces, surrounded by sharp little trenches.

The ovoid masses are uniformly arranged as regards the direction of their long axes, and each one is surrounded by a sharp border half an inch wide, of a dark greenish gray color, which has been more resistant to weathering agencies than the rest of the rock. The ovoid masses present as the result of weathering a rough or pimpled surface of porous aspect and bleached greenish white color. The interstitial filling is firmer in texture and softer than either the ovoid masses or their border, and is intermediate between them in color, with a brownish yellow tinge.

In the hornblende schists this ovoid structure in the rock takes a somewhat different aspect, and presents the appearance of thin anastomosing sheets of dark green, soft chloritic material, sometimes enveloping completely ovoid or irregularly shaped portions of the hornblende schist, and at others losing themselves in a tapering, disconnected fashion in the main mass of the rock.[1]

It is evident upon the most superficial examination that this structure is in no way "concretionary," as that term is commonly understood. Nor is it possible to suppose that the harder ovoid masses were originally ejected fragments, which have become imbedded in a finer matrix of volcanic material forming a true agglomerate. A sufficient objection to this hypothesis is the fact that these harder masses so frequently fit together like parts of a mosaic.

In many instances the spherical or ovoid form of the disjointed fragments is so perfect that the structure strongly resembles the spheroidal parting, developed in a latent form in eruptive rocks by cooling, and made more distinct by weathering. This, which is really a perlitic structure on a large scale, frequently extends through large masses of eruptive material; and the descriptions and photographs kindly furnished the writer by Mr. Whitman Cross, who has studied it in Colorado, indicate many points of striking resemblance to the structure of the Lake Superior greenstones. It is quite possible that the phenomenon may in certain cases be due to contraction, although in others the irregular shape of the fragments, as well as their occurrence in fragmental rocks, indicates another origin.

A structure showing many points of resemblance to that here described is presented by the well known green schists (grüne Schiefer), occurring near Hainichen, in Saxony, and the explanation afforded by the study of their very favorable exposures may assist our understanding of the parting in the Lake Superior greenstones. The fragments of the Saxon green schists, in spite of the great difference in their size (varying from that of a pea to that of a house), are so rounded that they were formerly regarded by C. F. Naumann as a conglomerate.[2] Never-

[1] Geol. and Nat. History Survey of Canada, Annual Report for 1885 (new series, Vol. 1); Report CC on the Lake of the Woods, by A. C. Lawson, pp. 52, 53.

[2] Erläuterungen zur geogn. Karte des Königreichs Sachsen, pt. 1, 1834, p. 69.

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theless their fitting together convinced subsequent observers that the structure must be due to brecciation in situ.[1] These rocks have more recently been carefully studied by A. Rothpletz, who was able to trace the structure downward into a series of interlacing joints, and who explains the rounded character of the fragments and the production of much of the interstitial material by the rubbing together, under the action of intense orographic pressure, of a mass already finely subdivided by cracks. Fig. 4 of Rothpletz's plate gives a fair representation of some of the Lake Superior occurrences.[2]

The hypothesis of the mechanical origin of this curious parting in the greenstones and greenstone schists seems best to explain the following facts:

(1) Its occurrence in fragmental rocks.

(2) The often very irregular shape of the fragments.

(3) The interlocking of the same into a mosaic.

(4) The fact, noticed by Lawson, that the thickness of the interstitial layer is independent of the size of the fragments.

(5) The fact, also noticed by the same observer, that the interstitial layer in horneblende schists often loses itself in the rock without completely surrounding a fragment.

(6) The identity in petrographical character of all the cores in the same mass.

(7) The similarity, except where it is more altered, of the interstitial material to that forming the ovoid cores. At the Carp River locality (see p. 176) the cores contain small white feldspar crystals, which are also present in the layers which separate them.

COARSE GRAINED DIKE ROCKS.

The fine grained aphanitic greenstones and greenstone schists which prevail over the southern Marquette area are intersected by many bands of coarser material whose eruptive character is still evident in their microscopic structure. These represent later dikes of a basic character which have broken through the older rocks, and which on account of their more recent eruption are less altered. One of the most typical of these is exposed on the small island near the end of the Cleveland ore dock in Marquette. This small island consists of two portions connected by a narrow neck. The southern part is composed of a hard, compact, brown rock, which is sometimes quite coarse grained or porphyritic. Its color and the abundance of epidote which is macroscopically visible indicate extensive alteration. Under the microscope a specimen from this locality, No. 11649, is seen at a glance to be a typical diabase. Although every vestige of the original pyroxene has been

[1] Naumann: Erläuterungen der geogn. Karte der Umgegend von Hainichen im Königr. Sachsen 1871, p. 11. Rud. Credner: Das Grünschiefersystem von Hainichen, Zeitschr. für die gesammten, Naturwiss., vol. 47, p. 127, 1876.

[2] Ueber mechanische Gesteinsumwandlungen bei Hainichen in Sachsen, part 2. Zeitschr. Deutsch. geol. Gesell., vol. 31, pp. 374–397. Pl. IX, 1879.

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replaced by a finely fibrous green hornblende (uralite), yet the characteristic ophitic or diabase structure is still perfectly preserved. The lath-shaped feldspar crystals are but slightly altered and the spaces between them are as sharply defined as when the rock first solidified.

The northern portion of this little island shows the same diabase in a much more altered form. The rock has a pale greenish color, and, though quite massive in the center, is schistose on either side.

Nos. 11651 and 11652, the former from the massive and the latter from the schistose portion of this rock, offer additional examples of the fact so frequently observed in the Menominee River greenstones, viz, that the feldspar of those rocks which have been subjected to the greatest pressure is more broken, but, as a rule, less altered than that in rocks which have experienced less violent mechanical action. Both of these specimens show positive evidence in their structure that they were once diabases. In both the ophitic arrangement of the constituent minerals is still distinct, but in the more massive rock the chemical alteration has progressed much further than in the other. Here the lath-shaped feldspar crystals are preserved in outline by the various secondary products which supply their place. Fibrous hornblende and leucoxene are abundant and nowhere, in either the thin section or hand-specimen, is there visible any parallelism of arrangement among the components. In the schistose rock, on the other hand, chlorite has largely replaced the hornblende, but the feldspar is almost unaltered. The long, lath-shaped crystals are broken and faulted—the fragments of a single individual often being separated a considerable distance—but in spite of this the substance is as fresh and the twinning-lamellæ are as sharp as in a recently solidified rock. Few better examples could be found of the evident action of pressure upon a solid rock mass. There has been a crushing and a consequent development of schistose structure which the microscope reveals with great distinctness. Along lines where an actual slipping took place, fibrous hornblende, chlorite, and calcite have been quite abundantly developed.

No more typical exposure of the greenstones of the southern Marquette area can be found than that seen in the high hill which rises between Whetstone Brook, the State road, and the railroad. (D on the map, Pl. VII.) The freshest rock obtained from the summit of this hill, No. 11724, is one of the best preserved diabases found anywhere south of the Eureka series. The feldspar is perfectly fresh but is much broken and faulted, as in the specimen (No. 11652) last described. The interstices between the fragments are filled with chlorite. The allotriomorphic pyroxene is now largely replaced by paramorphic hornblende, although cores of the original mineral are not infrequent in the center of the hornblende areas. Apatite, ilmenite, and leucoxene are also present.

Nos. 11646, from the southwest corner of the railroad crossing on Front street, Marquette (see on the map, Pl. VII.), and 11695, collected just

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north of the state road (in the center of Sec. 27 T. 48 N., R. 25 W.), are also well defined uralite diabases. In both the structure is still intact and the feldspars are generally well preserved, though the augite is wholly uralitized. One rock of exceptional character (No. 11687) which occurs within the limits of the southern Marquette area, must not be passed over without notice. This outcrops in a small exposure at the end of the road leading westward from Marquette to the Eureka shaft, about two miles from the city (see map, Pl. VII). It is of a light brownish color, and, in spite of an advanced state of chemical alteration, it shows plainly the effects of great pressure. It appears once to have been a gabbro, very similar to that occurring at Sturgeon Falls, on the Menominee River (see p. 67), but now its original components and structure have both disappeared. Interlacing, lenticular areas produce a decided "microflaser" structure, which, in places, even resembles the fluidal appearance of certain vitrophyres. The minerals now present are a very pale chlorite filled with sharp epidote or zoisite needles, saussurite, quartz, calcite, ilmenite, leucoxene grains, and winding bands of a clear, brown, isotropic substance which looks like opal. This rock appears much shattered in the field and it is in immediate contact with the thin, fissile schists in which the Eureka shaft is sunk.

GREENSTONES SOUTH OF THE QUARTZITE.

Some distince south of the Carp River, in the west half of the NW. ¼ Sec. 6, T. 47 N., R. 24 W., below the limestones and quartzite, a few much contorted and altered greenstones appear just on the contact with the granite which incloses the Marquette basin on the south.

No. 11778 may still be recognized as a diabase, though it now contains only saussurite, chlorite, epidote, quartz, and leucoxene.

Nos. 11774 and 11775 are from the same greenstone band, the former massive, the latter schistose. They do not resemble any other rocks in the Marquette area, but they find their analogues in certain remarkable rocks on the south bank of the Carp River, where this is crossed by the road leading northward from Teal Lake (see succeeding section, p. 175). Sharply defined crystals of reddish feldspar are imbedded in a bright green mass of chlorite and serpentine. The feldspars, although not pulled apart as in rocks which have been subjected to a stretching, show evidences of the action of enormous pressure. Remnants of hornblende, from which the serpentine was probably derived; ilmenite, surrounded by leucoxene; and round grains of bright red iron hydroxide are also present in this rock. In the schistose modification, the constituents are pulled out into parallel bands. The feldspars are lath-shaped and smaller, and, without any loss of sharpness in their outline, they are replaced by calcite, which is surrounded by an opaque black rim. Certain bands in this rock are much finer grained and present the feldspar and hornblende in a much less altered condition.

No. 11779, from this same locality, is one of the best specimens any-

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where collected to show the effects of rock-stretching. It appears once to have been a granite porphyry, but is now very schistose and is colored green by the secondary chlorite. Its groundmass is a felt-like aggregate of sericite, quartz, and chlorite with a perfectly parallel arrangement of the constituents. The large porphyritic feldspar crystals are much broken and pulled apart, always in the direction of the foliation, as shown in Pl. XIV, fig. 2. Large calcite individuals are surrounded by bright green chlorite, and both of these minerals may represent original biotite or some bisilicate.

ROCKS OF THE NEGAUNEE AREA.

As has already been stated at the beginning of the preceding chapter, two points were selected for the study of the more western portion of the Marquette greenstone belt. One of these was the mining town of Negaunee, situated at the southeast corner of Teal Lake, about twelve miles west of Lake Superior. The town itself is on the iron-bearing Huronian rocks, south of the greenstone belt, whose southern edge skirts the northern shore of Teal Lake. Both east and west of the lake the greenstones are bounded on the south by the narrow ridge of white quartzite, whose termination is Mount Mesnard.

From this quartzite two sections, three miles apart, were run northward to the granite and Huronian rocks, which here divide the greenstones into two separate areas. The more southern of these, which we will designate as the Negaunee area, resembles in its general character the region south of the Eureka series near Marquette; while the region north of the Dead River, which will form the subject of the succeeding section, is much more like the northern Marquette area.

The greenstones occupying the region north of Negaunee do not occur in continuous exposures, but rise out of the plain composed of glacial and later deposits in the form of rounded knobs. Both the longest axis of these knobs and the approximately parallel rows in which they are arranged follow the east and west strike, common to all the rocks of this region. The greenstones are, for the most part, of the much fissured and brecciated, light green and aphanitic variety, described in the last section. They are also very commonly associated with the same coarser and more crystalline eruptives, probably of a much later age, that we encountered south of Marquette.

As will be readily seen from an examination of Dr. Rominger's map the Huronian rocks around and south of Negaunee and Ishpeming are also penetrated by numerous greenstones. These, as a rule, resemble the more crystalline and later intrusions of the greenstone belt proper, and they may have been contemporaneous with them.

APHANITIC GREENSTONES.

The main mass of the greenstone belt near Negaunee is composed of the fine grained or aphanitic rock which has been described in the last

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section as characteristic of the region south of Marquette. They belong to Lossen's type of "dichte Diabase" and always show more advanced chemical alteration than the coarser rocks. This is to be explained by their finer grain and also from the fact that they are older and have been subjected to more dynamic action than the others. In the field these rocks are found to be much brecciated and not infrequently quite perfectly foliated. They also exhibit the peculiar spheroidal parting already described, p. 166.

The microscopical appearance of a fair average type of these aphanitic greenstones (No. 11747, from Baldwin's Kilns) is represented in Pl. X, fig. 2, but they show considerable variation in both structure and composition. In none is any trace of pyroxene now to be found, and yet they were probably once typical diabases. Their mineralogical differences are mainly dependent on the relative proportions of hornblende and chlorite. The preponderance of one or another of these minerals may be attributed to a more or less advanced stage of chemical alteration, but certain differences in structure have probably always existed. The grain may vary considerably in its coarseness, while the long acicular feldspar crystals, so abundant in some specimens, are wholly wanting in others.

No. 11736 was collected on the road from Negaunee to Baldwin's Kilns, just beyond the Carp River, from about the center of the SW ¼ of the NE ¼ of Sec. 29, T. 48 N., R. 26 W. It is comparatively coarse grained and little altered. Under the microscope it appears as a confused aggregate of fibrous hornblende, a cloudy, opaque, indeterminable substance and some original feldspar whose crystals are much broken.

No. 11744, obtained from an isolated knob of greenstone, situated in the SW ¼ of the NE ¼ of Sec. 28, T. 48 N., R. 26 W., on the longer road to Baldwin's Kilns, about one mile east of where the last specimen was collected, is much like it in appearance and microscopic character. The only differences are due to the more advanced alteration of the latter rock. Here chlorite is abundant and the feldspar hardly visible.

No. 11745, from the same road as the last, but much nearer the Kilns, shows the spheroidal parting or brecciation in a very perfect manner. The grain is very fine, and the incomplete skeleton-like forms of porphyritic feldspar crystals are numerous. The mass itself is now largely chloritic, but looks as if it might once have been a finely porphyritic rock.

No. 11747, found at the same locality, is the one from which Pl. X, fig. 2, was drawn. It is similar in structure to the last specimen, but its grain is coarser, and fibrous hornblende is still abundant in its groundmass. The porphyritic feldspar crystals are broken, faulted and separated.

No. 11748 is a schistose modification of 11747. This rock has a much finer grain than the other, but no evidence of schistose structure is ap-

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parent under the microscope. The chemical alteration has progressed so far that hardly any of the substances remaining have much action on polarized light; nevertheless, faint traces of small acicular feldspar crystals are visible.

One massive greenstone, No. 11740, found just north of Baldwin's Kilns, in the NW ¼ of Sec. 21, T. 48 N., R. 26 W., is striking on account of its being mottled with round white spots from 5^{mm} to 6^{mm} in diameter. The rock is somewhat darker than usual in a rim around these spots, and the whole effect is exactly that of a variolite. Under the microscope the rock itself is found to be composed almost wholly of green fibrous hornblende, together with some opaque grains and saussurite. The round whitish spots are very largely composed of saussurite or a very fine mosaic, in which sharply defined hornblende crystals are imbedded. They do not show the least trace of a radial or sheaf-like arrangement, such as is characteristic of a true variolite. These spots are not unlike those found in the banded greenstones of the Brook section (see p. 157) in their composition and structure, but they are very much more regular and uniform in their shape.

Other specimens of these aphanitic greenstones, as for instance Nos. 11793, 11795, 11796, and 11797, collected along the line of the old logging road, which leads from the eastern end of Teal Lake northward to Johnson's Camp, in the SE ¼ of Sec. 13, T. 48 N., R. 27 W., are quite like those above described from the neighborhood of Baldwin's Kilns.

COARSELY CRYSTALLINE GREENSTONES.

No. 11749, collected in the extreme northeast corner of Sec. 21 T. 48 N., R. 26 W., northeast of Baldwin's Kilns, is an unusually beautiful rock. The structure is coarse grained and rather granular, in spite of the feldspar crystals being idiomorphic. The large individuals of hornblende also, to some extent, have their characteristic crystal form. They are frequently changed to chlorite or to fibrous hornblende, but still oftener, although bleached to a pale green color, they retain their compact texture and show a twinning structure. There are no present indications that this rock ever contained pyroxene, and it is therefore to be designated as a diorite. The hornblende shows, in the process of its alteration, a curious tendency to concentrate the deep green color around the periphery of the crystals; also the fraying out of their edges into hornblende needles similar to those described by Becke and Van Hise as secondary growths, produced by regularly orientated accretions of hornblende substance. All of these features are shown in Plate XII, fig. 1, which represents the microscopic appearance of this rock. The feldspar is filled with epidote or actinolite needles. Large areas of bright green chlorite also occur which contain sometimes sharp epidote crystals, but more commonly fibrous hornblende. Leucoxene after ilmenite is abundant.

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No. 11739, from the southeasterly portion of the SW ¼ of the NW ¼ Sec. 21, T. 48 N., R. 26 W., just north of Baldwin's Kilns, is a dioritic rock much like the last, but it is considerably more altered. The hornblende is more fibrous, the feldspar more saussuritized, while the original structure is also beginning to suffer.

No. 11746 was taken from a well marked dike which intersects the spheroidally parted, aphanitic greenstones, near Baldwin's Kilns. Here the diabase or ophitic structure is perfectly developed, and there is no reason to doubt that the pale green, fibrous hornblende, which now fills the allotriomorphic spaces between the lath-shaped feldspar crystals is secondary after augite. The most interesting feature of this rock is its amygdaloidal structure which was observed in no other Marquette greenstone. Several small amygdules are filled with brightly polarizing epidote, while one large circular cavity, measuring four millimeters in diameter, has its sides coated with radiating epidote needles and its center filled with calcite.

No. 11741 is the rock exposed at Baldwin's Kilns. It is much jointed but quite massive. Under the microscope it appears like the specimen last described, except that it is finer grained and devoid of amygdaloidal cavities. The structure of this rock is perfectly preserved. It was once a typical diabase, although now no trace of pyroxene remains.

Another of the more coarsely crystalline dike rocks of the Negaunee greenstone belt was obtained near the granite contact in Sec. 13, T. 48 N., R. 27 W., two and one-half miles north of Teal Lake. This (No. 11791) is a typical uralite diabase, as is shown both by the distinct traces of ophitic structure and by the frequent cores of pale reddish brown augite which still remain in the fibrous hornblende. Ilmenite, partially changed to leucoxene, is also present in forms especially characteristic of diabase. The original structure has been considerably obscured by chemical changes. The feldspar is partly recrystallized to a mosaic, and epidote, chlorite, and quartz have been secondarily developed.

As has been above remarked (p. 171), the greenstones which occur so abundantly in the iron-bearing Huronian rocks both north and south of Negaunee are apparently identical with the coarse grained, younger rocks of the greenstone belt proper. Still they show the effects of having been subjected to enormous pressure which has frequently produced in them a schistose structure; and as this is, in every case, conformable to the general strike of all the rocks of this region, we must conclude that these greenstones were intruded before the folding of the Huronian sediments was completed.[1]

Specimens were collected from the prominent exposures of these greenstones near the town of Negaunee. They are all rather coarse uralite diabases of the type last described from the greenstone belt.

[1] See sections by Brooks, Atlas to Geol. Survey Michigan, Pls. III and V.

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No. 11754, collected from the SW ¼ of the SW ¼ Sec. 6, T. 47 N., R. 26 W., near the mouth of the Jackson mine, has a well preserved diabase structure. Its pyroxene is wholly changed to pale secondary hornblende; its feldspar is filled with epidote, while chlorite and leucoxene are common.

No. 11755, from a high hill somewhat farther east, is essentially the same rock. It contains epidote and chlorite even more abundantly.

No. 11756 was collected from a small greenstone knob just east of the hotel (Breitung House) in Negaunee. This rock has been quarried and may be plainly seen to have been rendered partially schistose by pressure. Under the microscope it is like the preceding rocks except that alteration has here progressed further—so much so as to have obscured, though it has not obliterated, the original diabase structure. Chlorite, epidote, and calcite are among the prominent constituents.

Nos. 11758 and 11759 are from the greenstone bluffs which skirt the southern shore of Teal Lake near its eastern end. The former is the most massive, the latter a schistose variety of this exposure. The massive rock is a uralite diabase of the ordinary type, retaining its original structure and also occasional cores of red augite in the masses of secondary hornblende. Besides the usual chlorite, epidote, and leucoxene, there is considerable quartz present in this rock. The second specimen, taken from the schistose band on the south side of this greenstone ridge, shows evidence of intense mechanical and chemical action. The original structure has almost wholly disappeared, while its component minerals are calcite and chlorite, together with a little quartz and leucoxene. Rarely these secondary products have preserved the outline of lath-shaped feldspars, which show that they have been much broken and pulled apart by the stretching action to which the rock has been subjected.

THE STRETCHED FRAGMENTAL ROCKS ON THE CARP RIVER.

An enigmatical group of rocks was met with near the center of the Negaunee greenstone belt, where the old road leading to Johnson's logging camp crosses the Carp River. This locality is in the NE ¼ Sec. 25, T. 48 N., R. 27 W. The first rock south of the river is exposed in a low wall which rises just west of the trail. (No. 11798.) This is apparently a dark colored, schistose greenstone, standing nearly vertical and filled with red granite fragments of all shapes and sizes, though generally with well rounded outlines. The dark green matrix also contains much of the red material in a finely divided form, often resembling sharp crystals. The rock itself is much brecciated and cut by cross-gashes, as if it had been subjected to a stretching tension.

Under the microscope the dark green portion of this rock is found to consist entirely of chlorite, the scales of which are arranged parallel to each other and to the cleavage planes of the mass. Its color, when free from inclusions, is a clear, bright green, but it frequently contains con-

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siderable black or brownish opaque material, which is arranged in long, sinuous lines following the foliation. The reddish inclusions are almost altogether orthoclase, colored by a fine, unevenly distributed, globulitic dust. A striated feldspar may also be occasionally observed. The orthoclase is partly in sharply defined crystals, but more commonly in irregular and angular fragments. These range through all sizes down to the most microscopic dimensions. The smallest bits are locally scattered so thickly through the chlorite as to give the rock a decidedly clastic appearance.

The chlorite matrix is of that peculiar character which we have already had occasion to notice as characteristic of stretched greenstone, particularly in the Menominee Valley (see pp. 82, 83, and Pl. XI, fig. 2). This chlorite must have crystallized after the orthoclase fragments had come into their present relative positions, as may be seen from the relations of its scales to the feldspar, and also by the bending around these fragments of the sinuous bands of opaque matter which the chlorite sometimes contains. We may go even further and assert that the chlorite could not have been formed prior to the stretching action. Proof of this is to be found in the fact that some of the orthoclase inclusions may be plainly seen to have been broken during this process and their fragments to have been separated but a short distance and always in the direction of the foliation; *and yet the same chlorite which forms the whole matrix fills these late fissures.*

It is impossible to state anything positive with reference to the origin of this chlorite; and still its universal presence in the stretched greenstones would indicate that this particular form of dynamic action upon a mass of the proper chemical composition is, in some way, necessary, or at least very favorable to its production.

No. 11799, from the same locality, is essentially like the last specimen, except that the included feldspar is lighter colored and perhaps more altered to kaolin or muscovite. The matrix is not so purely chloritic, but contains much finely divided feldspar. The stretching action is here even more apparent, a single feldspar crystal being pulled out to over double its original length and its fissures being filled with the same green chlorite.

If we trace this ridge farther south it develops into a finer grained and more schistose greenstone, which is free from the larger granitic inclusions but is mottled with small white spots (No. 11800). These are found upon closer examination to be feldspar crystals. Under the microscope this rock is quite like those above described, but it shows much more distinctly the effects of dynamic action. The grain is very uneven. In some places the feldspar crystals are thickly crowded and are cemented by the usual chlorite in which epidote is abundant; in other places the matrix is a very fine grained aggregate of chlorite, sericite, quartz, and feldspar, containing considerable opaque substance and possessing a micro-flaser structure produced by the winding of its

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parallel bands about the occasional feldspar inclusions. These latter are much pulled out in the direction of the foliation and have their interstices filled, sometimes by the chlorite, but oftener still by calcite.

No. 11801 is a more weathered specimen of this same rock, which shows with great distinctness the spheroidal parting described above (see p. 166). The stretching action is here displayed by the pulling out of the spheroids into a system of interlocking lenses, as represented in Fig. 27. Under the microscope this rock shows the effect of the me-

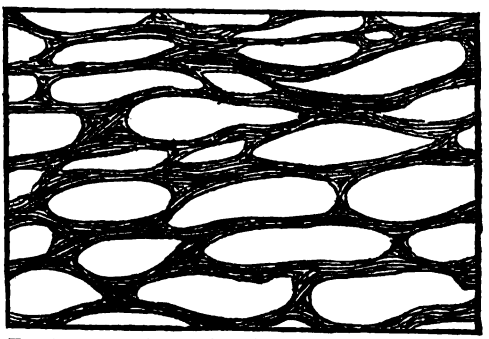

FIG. 27—spheroidal parting of aphanitic greenstone produced by brecciations; drawn out into lenses by pressure. Scale same as in Fig. 26.

chanical action in the extremest degree. The matrix is very schistose and consists of a gray, indeterminable, almost isotropic mass in which minute flakes of sericite are distinguishable. The feldspar crystals are so altered that they seem to grade imperceptibly into the matrix, leaving their original shapes but indistinctly outlined. The dark green chlorite occurs only in rare patches.

No. 11802 is from the interstitial mass between these lenses. It is a finely fibrous, felt-like, sericitic mass, in which the scales are so strictly parallel that the entire slide extinguishes the light between crossed Nicol prisms almost like a homogeneous crystal. There are besides present only small patches of a light brown, isotropic substance, some little quartz in isolated areas, and long stringers of leucoxene, out of which minute but sharp, highly refractive octahedrons have been developed (anatase ? cf. No. 11130, p. 131).

No. 11803, also from this interstitial material, contains white feldspar crystals like the more massive cores. A microscopic examination shows that this specimen is in all respects identical with the rock which it surrounds. The schistose structure is due to a crushing accompanied by a tension in one direction. The effect of this is so striking on the included feldspar crystals that it has been selected for illustration. (Pl. XIV, fig. 2.)

After a careful study of this suite of rocks, which is distributed over a considerable area, it is impossible to escape the conviction that they are of a fragmental character. Neither their structure nor their

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mineral composition resembles that of any known eruptive rock while the sudden variations in grain, the irregular and angular shape of the feldspar inclusions, and, above all, the extreme differences in the size of even such of these inclusions as lie side by side can be reconciled only with a clastic origin. Still these rocks do not bear the stamp of true sediments, and the most probable hypothesis of their nature which the writer can offer is that they are deposits of volcanic ejectamenta which have subsequently been rendered schistose by dynamic agencies. The irregular and angular fragments of red granite must be regarded as material broken from off the underlying rock masses and hurled out by the violent explosive force, along with much finer rapilli, sand, and ashes. These rocks seem to agree very closely with the agglomerates described by Mr. A. C. Lawson, of the Canadian Geological Survey, as attaining an extensive development in the Lake of the Woods region. These are filled with angular fragments and have also been subjected to great pressure. Mr. Lawson's opinion regarding the origin of these agglomerates is the same as that above advanced.[1]

The presence, as here, of the spheroidal or lenticular parting in rock of fragmental origin is sufficient to show that it must be a mechanical and not a molecular phenomenon.

ACID ROCKS.

There were no acid intrusives encountered within the Negaunee greenstone area proper, nor do the granites which skirt the northern edge of this belt present any points worthy of especial note.

No. 11790 is the granite in immediate contact with the greenstones at the end of the section which was run northward from Teal Lake. It was found at the Johnson logging camp in Sec. 13, T. 48 N., R. 27 W. This is a typical granitite in which quartz is not very abundant. The biotite is quite altered and bleached. The feldspar is particularly distinguished by its beautiful zonal structure, which the incipient kaolinization has brought out all the more distinctly. This feldspar shows the effects of pressure, and in one instance this can be plainly seen to have resulted in the production of a microcline structure. One small, sharp crystal supposed to be orthite was observed in this rock. Apatite and zircon also occur, and occasionally a few rutile needles are secondarily developed in the altered mica.

No. 11738 is from the granite in contact with the greenstone just north of Baldwin's Kilns. This rock is completely crushed, the constituents being in some cases so pulverized as to give the specimen, when seen under the microscope, almost the appearance of a fragmental deposit. The mica is here much altered, and among secondary products has given rise to an abundance of most delicate rutile needles, which often form the characteristic twins.

[1] Geol. and Nat. Hist. Survey of Canada. Ann. Rept. for 1885, p. 49, CC.

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Here may conveniently be recorded some observations made on the quartzite of the ridge which borders the greenstones on the south in the neighborhood of Negaunee. This quartzite mass is composed on its northern or lower side of compact, even grained, thinly laminated rocks, varying in color from black to the lighter shades of green, yellow, and drab. At one point, near the northeast corner of Teal Lake, these have been quite extensively quarried as novaculites, although they are of a different character from the novaculites occurring near Marquette. These rocks have the usual east and west strike and dip steeply to the south. These so-called novaculites are again underlaid by conformable beds of a coarse, white quartzite conglomerate, which in its turn is in immediate contact with the greenstones. The best locality for seeing these contacts is on the wood road leading northeastward from the slaughter-house on Teal Lake. (NW ¼ Sec. 31, T. 48 N., R. 26 W.)

No 11785 is a nearly black specimen of the novaculite. Under the microscope the fragmental character of this rock is at once apparent. It is composed of irregular quartz and altered feldspar grains in nearly equal proportions. In the finer cement biotite has abundantly crystalized. An occasional zircon crystal would seem to indicate that the rock is the stratified debris of an old granite. The present foliation of these novaculites is to be regarded as a slaty cleavage due to pressure, rather than an original stratification.

The conglomerate between the novaculite and greenstone, and forming the base of the Huronian quartzite, is composed of large grains and pebbles of granitic quartz, imbedded in a fine, silky matrix of sericite. (Nos. 11787 and 11788.)

ROCKS OF THE NORTHERN AREA.

The second point selected for the examination of the western portion of the Marquette greenstone belt is near the center of Sec. 9, T. 48 N., R. 26 W. Here a camp was established and from it were studied the greenstones represented upon Dr. Rominger's map as occurring north of the Dead River. The rocks within this area present a much more varied character than those of any of the other areas examined. Indeed, although a considerable collection of specimens was made, it is not for a moment supposed that all the types of massive rocks which occur in this region were obtained. Enough, however, will be noticed to indicate the general character of the area and at the same time to illustrate the extreme variety offered by different, and often nearly contiguous, outcrops.

In its chief features, this area more closely resembles the northern portion of the belt near Marquette, just as the southern branch near Negaunee, as stated in the preceding section, is more like the southern Marquette area. Still, the more recent eruptive rocks which penetrate the banded green schists far exceed, both in amount and variety, those to be found nearer Marquette.

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UNALTERED BASIC INTRUSIVES.

At the falls of the Dead River, in the southwest corner of Section 9, the "arenaceous slate group" of Rominger is well exposed. This consists here of thinly bedded slates which strike N. 75° W. and stand nearly vertical, with perhaps an inclination to the south. The upper part of the fall is a steep incline over the slates, but the lower portion is a clear fall of from twenty-five to thirty feet, occasioned by several trap dikes which run nearly east and west. These are coarse grained, fresh, and sometimes porphyritic.

No. 11814, from one of these dikes, is found, under the microscope, to be a very fresh and typical olivine diabase, quite like that of the great dike on Lighthouse Point, Marquette. The structure is typically ophitic. The porphyritic appearance is occasioned, not by single individuals of feldspar, but by concretionary aggregates of this mineral. The olivine, which frequently presents crystal outlines of great sharpness, is sometimes completely, sometimes only slightly serpentinized.

No. 11826 was collected from an outcrop beside the road at the southwest corner of Sec. 10, T. 48 N., R. 26 W. It has every appearance of being in place, but the character of the rock, unknown elsewhere in this region, renders it much more probable that it is a portion of a huge glacial erratic which is nearly buried in the drift. Still, the petrographical interest of this rock makes it worthy of a description. A close examination shows it to be an olivine gabbro, perfectly fresh and peculiar on account of the abundance and beauty of its olivine. This constituent makes up a large percentage of the entire mass. It is present in extremely sharp and well formed crystals from 0.1 to 1^{mm} in diameter. These show the usual hexagonal cross-sections, due to the presence of faces of the prismatic zone and domes.[1] No signs of even incipient alteration are visible in this olivine. The augite and triclinic feldspar are both allotriomorphic, and form much larger individuals than the idiomorphic olivine which they inclose. Magnetite is abundant in sharp octahedral crystals, showing quadratic sections; while other irregular areas of an opaque black iron mineral may be ilmenite. These latter are often partially bordered by a dark brown mica. No other rock exactly like this is known to me, but in its general character it is allied to the olivine gabbros which play such an important rôle on the north shore of Lake Superior.[2]

ALTERED COARSE GRAINED ROCKS.

The coarser grained intrusive rocks, which penetrate the prevailing green schists of the northern area, have, as a rule, undergone a considerable amount of chemical alteration. This has more or less completely replaced the original minerals by secondary products; while, in some

[1] These crystals show indications of twinning, as described by Kalkowsky (Zeitschr. Kryst. u. Mineral, vol. 10, p. 17) but these are not as distinct as the sharpness of the crystals would lead us to expect.
[2] Cf. Irving; Mon. U. S. Geol. Survey, vol. 5.

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cases, it has also obliterated the original structure. Among these younger eruptive greenstones the same two types can be distinguished as in the Marquette area, viz, diorite and diabase.

Diorite—Nos. 11828 and 11829 are from an exposure thirty paces in width, on the line between Secs. 5 and 8, T. 48 N., R. 26 W. This rock is sometimes parted into parallel plates so as almost to resemble a slate. In the hand-specimen it is seen to be composed of rather large, well-formed hornblende crystals, which are often hollow at the center, and a reddish feldspar. The microscope shows that the two specimens are identical. The hornblende is idiomorphic, though without terminal planes; the feldspar, on the other hand, is wholly allotriomorphic. This latter mineral is almost free from twining striations, so that the rock were perhaps more properly termed a syenite. The hornblende preserves much of its compact structure and brownish color. It is frequently changed at the center to a mass of fibrous needles, or even to chlorite, while the exterior remains compact and unaltered. Apatite is very abundant; sphene and magnetite are not uncommon.

No. 11817, from a wide dike at the northwest corner-post of Section 9, of the same township, is of the same type as the last specimens, but more altered. Macroscopically tufts of hornblende crystals may be seen imbedded in a white feldspar substance. Under the microscope this feldspar appears to be mostly altered to a brownish saussurite, in spite of which, however, traces of a stout lath-shape are discernible. The hornblende is much altered to a fibrous form. It frequently has the emerald green color of actinolite, especially around the outer edge, where it is always darker and more compact than at the center. Ilmenite, accompanied by leucoxene, is abundant in the rock, though absent in the two last mentioned specimens. It will be noticed that this rock approaches much more nearly than the others to the diabase type, and yet there is no reason to believe that the hornblende is paramorphic after pyroxene. Although it is not compact, it still retains its twinning structure as one of its most common features.

A still more striking example of idiomorphic, lath-shaped feldspar in a diorite (a structure which Rosenbusch mentions as not at all uncommon in rocks of this class[1]), is to be found in No. 11831. This was obtained on the line between sections 5 and 8, just east of Nos. 11828, 11829, above described. It is entered in the field-notes as a coarse reddish diorite or syenite, having long, green hornblende crystals imbedded in a red feldspar. On account of its unstriated feldspar, this rock may perhaps be even more properly designated as an amphibole granite, although its structure is in many respects peculiar. (See Pl. XVI, fig. 2.) The feldspar is present in two distinct generations. The earliest of these yielded stoutly lath-shaped crystals, which are wholly idiomorphic. These are mostly unstriated, but have a zonal structure. They are internally changed to a grayish mass, which a

[1] Mikros. Physiog., 2d ed., vol. 2, p. 121.

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high magnifying power shows to be muscovite or kaolin, while their periphery is composed of clear and fresh feldspar substance. Between these feldspar crystals is a granular aggregate of quartz and a younger feldspar. This latter mineral is also unstriated (though sometimes possessed of the gridiron microcline structure) and much fresher than the older feldspar. With the quartz it frequently forms beautiful micropegmatitic growths.

Hornblende was most probably the original bisilicate constituent of this rock, but it has undergone an unusual alteration, i. e., the alteration to mica. This mineral can be seen under the microscope in brown areas of irregular shape, which have evidently been produced at the expense of the hornblende.[1] They are unevenly colored, being a darker brown in some places than in others. In some cases the new mica crystallizes in sharply defined hexagonal plates. Certain of these, which on optical examination prove to be basal sections, show cleavage lines parallel to the prismatic faces. These are the so-called pressure figures ("Drucklinien" of the German mineralogists), which are rarely visible in microscopical sections and are strongly indicative of pressure.

This secondary mica to a considerable extent has turned green by a reduction of its iron to a ferrous state. More rarely the alteration has progressed still further, resulting in complete bleaching, or even the production of chlorite. Apatite is very abundant in this rock; sphene is also common, but its crystals always surround ilmenite grains in such a manner as to suggest that the titanite has resulted from its alteration (see Pl. XVI, fig. 2). Chlorite also frequently surrounds the opaque iron mineral.

Of all the remarkable features which this rock presents, perhaps none is more striking than its hypidiomorphic structure and the presence of the feldspar in two distinct generations without the production thereby of a porphyritic structure. This is all the more noteworthy in a rock which from its mineralogical composition is to be strictly classed among the granites.

No. 11832, which occurs with the specimen last described, appears to the unaided eye as a compact, fine grained mass through which large glistening hornblende crystals are unevenly distributed. Under the microscope the groundmass of this rock is seen to be composed of lath-shaped feldspar crystals, which are altered sometimes to epidote, sometimes to sericite; allotriomorphic hornblende, frequently changed to chlorite; a little quartz and magnetite in grains and crystals. The sharp quadratic and hexagonal sections are sufficient to identify this species; but we must assume that it is a titaniferous magnetite on account of the very narrow leucoxene border which

[1] Rosenbusch mentions only parallel growths of hornblende and biotite. The present instance can hardly be so interpreted, while there is nothing surprising in an alteration which has been so frequently observed. (Cf. J. Roth: Allgemeine und chemische Geologie, vol. 1, p. 333, 1879.)

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frequently surrounds it. The porphyritic hornblende of this rock is sometimes regular, sometimes irregular in outline. It is a later crystallization than the groundmass, because it is always filled with the lath-shaped feldspars. This produces the structure which I have recently termed "poicilitic,"[1] and which is characteristic of younger porphyritic crystals, especially hornblende and pyroxene.

No. 11834, from a ledge 640 steps north and 20 steps west of the southwest corner of Sec. 4, T. 48 N., R. 26 W., is composed of stout, lath-shaped feldspar crystals and large individuals of fibrous hornblende. The former mineral suggests by its form that the rock was once a diabase; the hornblende, however, is not allotriomorphic, but is present in long, columnar crystals, which are generally twinned. One of these crystals is bent in the most unaccountable manner. It forms three-quarters of a circle (see Fig. 28), but no satisfactory explanation can be offered for this unusual shape.

On the whole, this rock is considerably altered. Epidote and hornblende needles are developed in its feldspar, while secondary quartz is quite abundant. In spite of the fibrous character of its hornblende, the structure of this rock is much more suggestive of a diorite than of a diabase.

FIG. 28.—Bent hornblende crystal. Greenstone No. 11834. Magnified 30 diameters.

Diabase.—Among the altered intrusive rocks, those which represent the diabase type are all uralite diabases. In none was any trace of the original augite observed.

In No. 11827, from 485 steps west of the southeast corner of Section 5, the structure is best preserved. Here the fibrous and in part bright emerald green hornblende retains exactly the allotriomorphic form of the diabase augite. The feldspar is largely altered to a brown, opaque saussurite, and leucoxene has replaced the ilmenite.

No. 11837, from 815 steps north of the southwest corner of Section 4; No. 11848, from 500 steps west of the southeast corner of Sec. 10, T. 48 N., R. 26 W., are both much more altered than the specimen last mentioned. The ophitic structure is best preserved in the latter, although epidote is abundantly developed, while it is altogether wanting in the former.

Other of these uralite diabases are finer grained.

No. 11825, from a somewhat schistose greenstone ridge, exposed near the center of the southwest quarter of Section 10, admirably exhibits the effects of crushing. The lath-shaped plagioclase crystals are still

[1] Am. Jour. Sci., 3d series, vol. 31, 1886, p. 30.

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wonderfully fresh, but are broken, faulted, and pulled apart, while their interstices are filled with the secondary chlorite usual in stretched rocks. There is a delicate granophyre or micropegmatite structure in this specimen—undoubtedly an original feature, as in No. 11675 (see p. 140). The pyroxene is wholly changed to a pale green, fibrous hornblende, which, to a considerable degree, produces the foliation. Large areas of brown leucoxene, of the variety most characteristic of altered diabase, are also drawn out in the direction of the schistose structure. In one instance this has altered to a network of dark rutile needles imbedded in a yellowish micaceous mineral, as described in No. 11070 (see p. 99, and Plate XIII, fig. 2).

No. 11830, from 700 hundred steps west of the southeast corner of section 5, is a very typical uralite diabase. The structure is still well preserved by the feldspars, in spite of needles of the fibrous hornblende having freely wandered into them. Traces of augite cores remain in this rock.

No. 11835 is a schistose rock from 640 steps north and 20 west of the southeast corner of Section 5. It has been much altered, and now consists mainly of a fine aggregate of fibrous hornblende, feldspar, quartz and calcite. In this lie large porphyritic crystals of hornblende which are wholly altered, especially in their interior.

BANDED GREENSTONES.

Striped and banded greenstone schists, like those of Lighthouse Point, Marquette, are very abundant in the northern area.

No. 11856, from an exposure near the northeast corner of Section 9, is macroscopically identical with the Marquette rocks. Under the microscope it would be designated as a hornblende schist. It consists of minute crystalloids of compact green hornblende, together with feldspar which is mostly changed to sericite. Zoisite in crystalloids, like those represented in Fig. 2, p. 27, and about the size of the hornblende, is also present. The structure of this rock is schistose, caused by the parallel arrangement of all the constituents.

Other banded greenstones from this region, like No. 11818, from near the southeast corner of Section 5; 11821, 850 steps north of the southwest corner of Section 4; 11839, 170 steps south of west quarter post of section 4, and 11841, 180 steps north of the same quarter post, are essentially like the specimen just described—mostly a mass of confused hornblende fibers with more or less feldspathic substance, quartz, and chlorite. The relative proportions of these components condition their different colors and cause the parallel striping.

These rocks are so similar to those occurring immediately north of Marquette, that we must apply to them the conclusion already expressed (p. 158) in regard to the origin of these green schists, and regard them as basic tuff deposits, which were contemporaneous with surface flows of diabase and subsequently profoundly metamorphosed.

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GREEN SCHISTS AND AGGLOMERATES OF DEER LAKE.

After the work on this paper was practically completed, my attention was called by Prof. Irving to a group of greenstone schists and conglomeratic rocks which lie in the western extension of the southern branch of the Marquette greenstone-schist belt. I was unable to study and collect these rocks in the field, but Prof. Irving furnished me with notes regarding their distribution and mode of occurrence, together with a suite of hand-specimens and thin sections for laboratory study. I incorporate the results of such a study in this place the more willingly because the occurrence of these rocks does not in the least differ from that of others closely allied to them, which I carefully examined in the neighborhood of Negaunee. The distinct evidence, moreover, which these rocks afford as to their mode of origin is of great value in confirming the conclusions already reached in regard to certain other analogous, though less distinctly characterized, occurrences.

These peculiar rocks are best exposed on the south side of Deer Lake in Secs. 33 and 34, T. 48 N., R. 27 W., Michigan, but they may also be advantageously seen farther to the northwest, in Secs. 20, 21, 29, and 30 of the same township.

The following field-notes were furnished me by Prof. Irving:

On the road going northward from Ishpeming to Deer Lake furnace a belt of quartzite dipping southward is crossed in the middle of Section 34. Immediately north of this quartzite follows a porphyritic greenstone of tolerably fresh aspect. This is exposed on the south side of the two knobs, which, on Dr. Rominger's map, lie to the southward of Deer Lake, to the east of the Carp River, and to the north of the road. To the northward of this greenstone succeed first some greenish schistose rocks without apparent agglomeratic character. These are represented by No. 12057. These schists soon grade, however, both across the strike toward the north and in the course of the strike toward the west, into a most strikingly conglomeratic rock, which appears to make up about all the hills in the northern half of Section 33, between the quartzite and the road leading to the Ropes mine.

Specimen No. 12058 is an obscurely conglomeratic rock, collected about 150 steps north of No. 12057. The conglomeratic character is best seen on a weathered surface. A particularly fine exposure may be seen just west of Deer Lake furnace (No. 12031).

Specimens No. 12029 are pebbles from a bold knob somewhat farther to the west. From the same point came Nos. 12023 and 12024, representing the conglomerate itself; and Nos. 12025 and 12026, from two dikes two and one-half and ten feet wide respectively. The smaller of these dikes cuts the conglomerate in a direction transverse to its foliation, while the larger runs parallel to this structure.

Throughout the conglomerate there is a tendency to schistose structure, which, however, is never very pronounced, and which varies considerably in its degree of development. It seems to be rather the result of the intersection of close joints cutting each other at a small angle than a true parallelism of structure. This foliation stands about vertical and trends in an eastern and western direction.

The pebbles vary in size from such as are two feet in diameter down to minute fragments. Pieces less than six inches in length are most abundant. Occasionally they appear well rounded, and this seems to be more particularly the case with the larger sized pieces; but more commonly they are sub-angular and flattened out in a direction parallel to the schistose structure. On an exposed surface these pebbles

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stand out by virtue of their whiter weathering. On a fresh fracture they are not nearly so apparent, but seem to differ from the rest of the rock by their finer grain and by their pinkish or greenish color; the body of the rock having usually a dark greenish gray tint.

No other kinds of pebbles were seen than those shown in the samples, which represent perhaps two phases: (1) A pinkish weathering felsitic (?) kind, and (2) a grayish weathering greenish and more schistose kind. But this distinction, written on the ground, seems hardly to be borne out by the specimens brought away. Certainly those of the first named kind are more abundant.

Occasional schistose bands a few feet in width and quite free from pebbles may be seen in the conglomerate, trending east and west. These, therefore, stand at a considerable angle with the schistose structure. They are the only signs of a true bedding in the rock, and if they do actually indicate a bedding are of very great importance, both as showing a discordance between the bedding and schistosity and also a nonconformity between these and the true bedded rocks lying just to the south. Indeed, neither these doubtful bedding bands nor the schistose structure perceptible in this conglomerate is concordant with the dip of the quartzite, which is toward the south at a moderate angle.

North of the road leading to the Ropes mine the only rock noticed, for a short distance, is represented by No. 12032, which does not show any conglomeratic structure, but which on the ground appeared very much like the pebbles in the conglomerate further south.

Still farther north, in the same township (T. 48 N., R. 27 W.), as, for instance, in the middle and eastern part of Section 21, and again in the southwest quarter of Section 20, and in the northwest quarter of Section 29, to the north of Dr. Rominger's serpentine area (peridotite area of Plate I, herewith) are other very similar rocks. Specimens 12036, 12037, and 12039 are from the SW ¼ of SW ¼ Sec. 20, while No. 12043 is from the NW ¼ Sec. 29. Among the exposures from which this last specimen was taken are some which seem to show the conglomeratic character of the Deer Lake rocks. It is not positive, however, that the obscure markings which they show are really those of pebbles.

Both the macroscopical and the microscopical examination of these specimens show that they have been subjected to an intense strain or stretching, which has resulted in the elongation of the component pebbles, and in the modification and partial recrystallization of the matrix, after the manner shown in Pl. XI, fig. 2, and in Pl. XIV, fig. 2. Nevertheless, the metamorphism attendant upon this dynamic action fortunately has not been sufficient entirely to disguise the tuff nature of the rock. In most cases this is still very apparent, and this occurrence is therefore of great importance in confirming the conclusions reached with regard to analogous, but more metamorphosed rocks, in the Marquette and Negaunee areas.

We must regard these tuffs or agglomerates as originally composed of the fine fragmental material of diabase. This consisted mainly of triclinic feldspar and pyroxene, mingled with more or less amorphous base, and stratified either by gravity or by the agency of water. Included in such a matrix were numerous true bombs of solid diabase and ejected fragments of other rocks, mostly of a more acid character.

As is well known, material of this kind is of all the most liable to undergo chemical alteration. This has been conclusively shown by the observations of Captain Dutton, quoted above (p. 159). In consideration

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of the great antiquity of the deposits here under discussion, therefore it need excite no wonder that little of the original material now remains. The rocks are largely composed of such secondary products as chlorite, sericite, epidote, quartz, and calcite. All traces of original pyroxene, or of possible olivine and glass, have wholly disappeared. The feldspar has, however, better retained its individuality. In some instances its substance is still quite fresh; and in others, where the substance is changed, the form is still easily recognizable. The same class of alterations has gone on in the solid portions of the agglomerates as in the finely fragmental matrix. The more basic fragments produce chloritic, the more acid sericitic, areas. Their original boundaries are, however, for the most part, very distinct, often more so in the field, or in the hand-specimen, than under the microscope. Where the dynamic action has been most intense a schistose structure has been developed in the fragments, which is quite continuous with that of the finer grained matrix. This is accompanied by a distortion or elongation of the included fragments, caused by crushing and recementing, whereby the sharpness of their outline is destroyed, and an apparent transition to the matrix is produced.

Specimen No. 12057, described in the notes as "a greenish schistose rock without apparent agglomeratic character," appears under the microscope at first glance as a confused aggregate of chlorite, calcite, and quartz, through which occasional large grains of yellowish green epidote are scattered. Characteristic forms of ilmenite, with leucoxene, some sericite, and delicate little rutile needles are also present. A more careful study of this section reveals the indistinct outlines of lath-shaped feldspars, which once formed the interlacing network of a granular diabase. These are so disguised by the new products developed in them—chlorite, sericite, and epidote—that it is only by an attentive examination with a low magnifying power that they can be recognized. They are, however, undoubtedly present, and the rock must therefore be regarded, not as a tuff, but as an extremely metamorphosed form of a massive flow, in which the profound chemical changes and the development of a schistose structure progressed together.

Specimen No. 12058, "an obscurely conglomeratic rock collected about 150 steps north of the locality of No. 12057," bears in the hand-specimen a close resemblance to the one last described, but under the microscope its different character is at once apparent. The feldspar substance is here less altered, and the rock is mostly composed of minute crystals or fragments of crystals connected by that peculiar aggregate of chlorite scales common in stretched basic rocks, where the direction of the scales follows the schistose structure. (See Pl. XI, fig. 2.) Occasional larger fragments of feldspar crystals are scattered through this finer mass, but these are always broken and irregular in shape. The chloritic substance has doubtless originated from the pyroxene or glass, while a vast number of the most delicate little rutile

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needles, arranged in long, sinuous bands, appears to represent the original ilmenite. Calcite areas also occur. A narrow white vein which traverses this hand-specimen possesses an interesting microscopic structure. The little fissure was first coated with chalcedonic quartz, and then with a layer of quartz crystals which projected their terminations into the opening. These possess a perfect zonal structure, due to the arrangement in successive layers of fluid inclusions. The remainder of the space was subsequently filled with carbonate.

Specimen No. 12031, from a point a short distance west of where the last mentioned pieces were collected, and Nos. 12023, 12024, 12029, and 12030, from another point still farther west, represent the agglomerate in its most typical development, and leave no doubt as to its true nature and origin. As in the specimens last mentioned, the matrix of the rock is of a grayish green color and the grain is mostly aphanitic, although frequent minute angular fragments may be detected by the aid of a pocket lens. There is always a more or less pronounced foliation developed in this matrix. The pebbles, which impart to the rock its agglomeratic structure, show most distinctly on a weathered surface. Here they present a white or pinkish gray color, which contrasts most sharply with the pale green of the inclosing matrix. On a fresh fracture the inclusions have a greenish gray color, but their compact, fine grain, like that of halleflinta, serves to identify them where the color fails. These massive felsitic fragments are of varying size and angular or subangular in shape (rarely well rounded). They are distributed through the matrix indiscriminately, the longest axes being by no means parallel, as we might expect in a sediment. The foliation of the rock appears to have been produced by a great tension, which has stretched the matrix and sometimes elongated the pebbles, sometimes broken them, and sometimes forcibly torn the solidified matrix away from them. The latter case is represented in Fig. 29, which represents

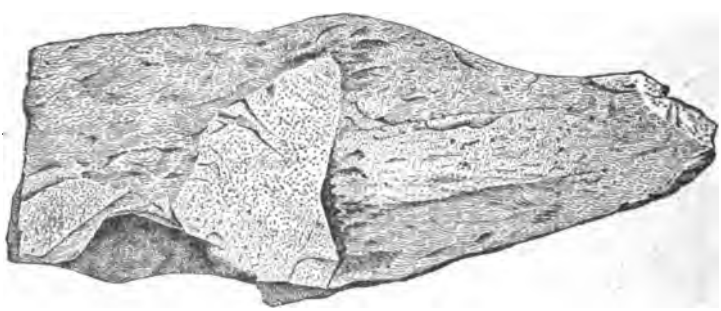

FIG. 29.—Weathered surface of a specimen of the Deer Lake agglomerate. Natural size. No. 12023.

the appearance of a weathered surface on specimen No. 12023. It can here be plainly seen that the longest axes of the pebbles stand almost at right angles and that the matrix has been forcibly separated by the stretching action, on each side of the central pebble.

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The microscopical study of these specimens adds much to our knowledge of the true structure of these agglomeratic rocks.

The matrix is found to be composed of very angular to subangular fragments, extending down to the minutest size. These generally still retain their form, although their original substance has undergone change to chlorite, epidote, and calcite. Small feldspar crystals or broken fragments of larger ones are scattered about, the substance of which has been altered in varying degree. In the chlorite especially, very sharp rutile needles abound. These seem to represent the titanium of an original ilmenite.

Unmistakable evidence of clastic structure is everywhere encountered; but this is not the clastic structure of a sediment. The angular shape, different substance, and enormous variation in the size of fragments lying side by side, all clearly indicate an agglomeration of volcanic detritus—and one, indeed, in which many of the original features are admirably preserved.

Among the smallest of the included fragments, those resembling a massive diabase in structure are not uncommon; but to judge from the statement in the field notes quoted above, as well as from the hand-specimens submitted to me for study, the larger "pebbles" or fragments are mostly composed of the lighter and felsitic rock. This is unfortunately too much altered to allow of a wholly satisfactory diagnosis. It may be best seen in section No. 12023, where it resembles a porphyrite. The groundmass still retains its ophitic structure, and is filled with well formed porphyritic crystals of plagioclase. No original quartz nor orthoclase could be detected; one or two chloritic areas, which most probably represent former augite or hornblende crystals, were, however, observed.

Specimen No. 12025 represents a narrow, transverse dike of massive greenstone, and No. 12026 a broader one of the same material, parallel to the schistose foliation. Under the microscope both are typical, though highly altered diabases. The former is aphanitic and has only a very indistinct foliation in the hand-specimen. Under the microscope the original structure is nearly obliterated; still, traces of it remain. Chlorite, calcite, quartz, and iron oxide are almost the only mineral components.

The second, coarse grained diabase, is entirely massive in the hand-specimen. It has an even green color, but cleavage surfaces of feldspar are frequent. Pyrite is also common in it. Under the microscope the typical diabase structure is perfectly preserved. The texture is quite coarse, and the feldspars mostly retain their twinning structure. The rock has been stretched, and these feldspars are much broken and have their fragments separated. The pyroxene is wholly altered to chlorite, epidote, and calcite, and the ilmenite is accompanied by leucoxene.

The rock occurring north of the road leading to the Ropes mine and

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directly west of Deer Lake, is devoid of conglomeratic structure. (No. 12032.) In the field it was noted to have a resemblance to the substance of the larger "pebbles," and this resemblance, to a certain extent, is borne out by the microscopical examination. The rock appears to be massive, and not a tuff; but it has been subjected to intense crushing and stretching action. It is full of porphyritic crystals, which are mostly altered to muscovite. The groundmass is principally composed of small rectangular feldspar crystals. All, however, are much broken and separated, and the interstices are filled with green chlorite scales. The main difference between this rock and that forming the compact felsitic pebbles in the agglomerate lies in the apparent orthoclastic nature of the porphyritic feldspar crystals, and in the chlorite which has been so abundantly developed in the groundmass.

The specimens from the more northerly areas, numbered 12036, 12037, 12039, and 12043, belong to the same category as those just described. No. 12036 is a confused aggregate of feldspar fragments of various sizes, together with some quartz and chlorite. Nos. 12039 and 12043 are almost too much altered to allow of any study. The former is a mass of nearly opaque decomposition products, and the latter is an almost continuous mat of sericite scales. No. 12037 alone appears like a massive rock—most probably a fragment included in the tuff. It is a hornblende granite, with but little quartz, composed principally of idiomorphic feldspar. The minute green hornblende needles fill the interstices between these square or rectangular crystals.

We may, therefore, consider the pyroclastic[1] nature of the Deer Lake conglomerates as beyond any question. They represent volcanic detritus, ejected by an explosive force at the earth's surface. In this way they form a most welcome but not unexpected support to the conclusions reached in regard to the other more highly altered rocks of the same class occurring in the Marquette region.

The term "agglomerate" here applied to these rocks is one in general usage among the English geologists[2] to designate a tumultuous assemblage of volcanic ejectamenta—bombs, foreign blocks, etc., of all sizes and shapes, cemented by a fine grained paste of volcanic ash.

The closest analogues to the Deer Lake rocks are the breccias, agglomerates, and tuffs, described by Dr. A. Geikie from St. David's, in Wales.[3] This author says, p. 93:

> The rocks of St. David's present features of interest and importance, not only in the palæozoic history of Britain, but in regard to general theoretical questions. They include, for example, perhaps the oldest group of lavas and tuffs, the relative date of which is known. They have been subjected to a process of metamorphism which has affected only certain beds or kinds of rock. They have been penetrated by masses of granite and quartz porphyry, around which another kind of metamorphism has been manifested. At a later period they have been injected with diabase dikes, etc.

[1] J. J. H. Teall, Geol. Mag., London, 3d series, vol. 4, November, 1887, p. 493.

[2] Cf. J. A. Phillips, Quart. Jour. Geol. Soc., vol. 24, 1878, p. 476, and A. Geikie Text-Book of Geology, 1882, p. 163.

[3] Quart. Jour. Geol. Soc., London, vol. 39, 1883.

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All this might have been written to apply equally well to the rocks occurring near Marquette.

With special reference to the tuffs, Dr. Geikie says:[1]

They vary likewise in texture from somewhat coarse breccias or agglomerates, through many gradations, into fine silky schists in which the tufaceous character is almost lost. Generally they are distinctly granular, presenting to the naked eye abundant angular and subanglar lapilli, among which broken crystals of a white, somewhat kaolinized feldspar and fragments of fine grained felsite are often conspicuous.

The matrix of these Welsh agglomerates appears to be generally green, while the included lapilli or "pebbles" are sometimes basic in character and of a greenish color; sometimes more acid, with a compact structure and pinkish color.

Their resemblance is thus seen to be very close to the Deer Lake agglomerates described in this chapter.

[1] Quart. Jour. Geol. Soc. London, vol. 39, p. 295.

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CHAPTER VI.

GENERAL RESULTS AND CONCLUSIONS.

ORIGINAL CHARACTER OF THE MENOMINEE AND MARQUETTE GREENSTONE AREAS.

In speaking of the geology of the Menominee and Marquette regions I refer, it must be understood, only to the greenstones and certain intimately associated acid rocks. No attention was paid to the quartzites, dolomites or shales of the younger, iron-bearing Huronian. With a view of obtaining a clear idea of the primary nature of these rocks we shall consider in succession: The evidence of their eruptive character; their original types and mineralogical composition; the conditions under which they were formed; and, finally, their succession in time.

EVIDENCE OF ERUPTIVE CHARACTER.

Field evidence.—This is more distinct in the case of the Menominee greenstones on account of the simpler character of their exposures. Here we find them extending in two comparatively narrow and nearly parallel bands for a considerable distance. Their color, weight, texture, and frequent massive structure are such as are associated with rocks of igneous origin, while in some cases, as just below the Lower Quinnesec Falls, they project out of the surrounding schists in the form of a high, precipitous ridge, suggestive only of a great dike. Although successive layers of these rocks differ considerably in composition, and though they possess within themselves well marked schistose varieties, yet they are sharply defined against the adjoining Huronian beds, into which they never pass by gradual transitions. Indeed, these rocks have been considered by many of the geologists who have examined them most carefully as of eruptive origin. Those, on the other hand, who have regarded them as either wholly or partially sedimentary have been able, as far as I know, to cite only two arguments in favor of their opinion. These are: First, the coincidence of the direction of these bands, and of their alternating component members with the general strike of all the rocks of this region; and, second, the frequent conformity of the schistose structure in these bands to the bedding of the adjacent sediments.[1]

Let us, however, consider whether these two facts are not wholly in accord with the supposition that these greenstones are of igneous origin.

[1] This conformity is by no means universal.

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If they were intrusive they would follow in their course the line of least resistance, which would probably be the direction of the bedding of the sediments. If, however, as seems from various considerations much more probable, these greenstones belong to a formation older than the Huronian, and if they were produced in the form of great igneous (and perhaps submarine) overflows which composed the bottom of the basin in which the iron-bearing sediments were subsequently deposited, then the great lateral compression, which so contorted these sediments and elevated them into their present almost vertical position, would have brought the underlying greenstones at the same time into just the position they now occupy. And if these greenstones had been formed as successive flows, differing more or less in structure and composition, in the process of upheaval they must have behaved like any other complex of horizontal beds and have produced conformable members of the series exposed in the Menominee valley, as is actually the case.

Now, also in regard to the second point of objection, if we admit that massive rocks may have a schistose structure (like a slaty cleavage), developed in them by pressure, then, in this case, the direction of this cleavage, perpendicular to the action of the pressure, must agree with the stratification of the now almost vertical sediments.

Nor is it necessary to assume that the schistosity of these rocks was wholly produced at the same time with the crumpling and slaty cleavages of the overlying detritals; since the same crumpling force may have worked in the same direction at two widely separated periods. Indeed, there is excellent reason to believe in two such periods, since the dikes, which in the Marquette region penetrated the greenstone schists subsequent to their being made schistose, have evidently themselves been subjected to further squeezing. These dikes appear to be contemporaneous with the sheets of greenstone interfolded with the detrital iron-bearing strata, which sheets themselves show a similar degree of schistosity with the dikes referred to. In the Marquette region there is generally a very noticeable difference as to the amounts of secondary cleavage in the greenstone-schist area, and in the strata of the overlying iron-bearing series, this being very much greater in the former case. Coincident with this difference is the frequent gentle bowing of the iron-bearing strata in this region, the dips of its layers being often quite flat, while the cleavage of the green schists always stands at a very high angle. In the Menominee region, on the other hand, the folding of the iron-bearing series is very much closer and slaty cleavage is much more generally developed. This would seem to indicate that the second period of squeezing was more intense in the Menominee area, and that it was, therefore, probably more instrumental in rendering the greenstones schistose here than in the Marquette region.

The arguments used by the defenders of the sedimentary origin of the Menominee greenstones can not therefore be regarded as valid.

On the other hand we may cite, as positive evidence that the foliation

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of the greenstones is a secondary feature, the fact stated by Major Brooks, that at the Four-Foot Fall this foliation is conformable to the adjoining clay-slate, which has a "strong cleavage and no distinguishable bedding planes."[1] Thus the schistose structure of the greenstone now agrees with the secondary slaty-cleavage of the sediment, which, of course, may or may not agree with its original bedding, since this is here obliterated. Furthermore, what foliation the greenstones possess may be traced in almost every case into a jointing, or into bands produced by the crushing attendant upon faulting and slipping, which has taken place within the rock-mass. Finally, the abruptness with which the foliation of the greenstones commences and breaks off in the direction of the strike is wholly inconsistent with the theory that it is due to original stratification. At the Four-Foot Fall, for instance, the greenstones strike almost at right angles to the river, and yet they are very schistose on the Wisconsin and very massive on the Michigan bank. Such cases are not uncommon while even more difficult to explain are differences in the strike of schistose bands which traverse a massive rock (like those observed at the Upper Twin Fall), unless we assume that they were produced by a force which acted unevenly and not in a constant direction.

The field evidence that the greenstones within the Marquette belt are of igneous origin is not so plain as that encountered in the Menominee valley. Although we find here unmistakable dikes of unaltered diabase and others of altered though still massive greenstone, yet some of the most important of these rocks, especially in the northern part of the Marquette area, are so regularly banded and stratified that we are obliged to seek the agency of water to account for their formation. Nevertheless, we are not obliged to separate even these greenstones altogether from the igneous rocks which accompany them. For reasons stated at length in Chapter IV, they may be most satisfactorily explained as tuff deposits, half volcanic, half sedimentary, which throw important light upon the physical conditions under which the more massive rocks were produced.

Strong collateral evidence respecting the original nature of the greenstones of both these areas may be obtained from a study of the acid rocks which are quite constantly associated with them. The indications of the eruptive character of these rocks are so unmistakable that it seems to have hardly ever been doubted by any one who has examined them. Large areas of granite occur on each side of the Huronian basins, both in the Menominee valley and near Marquette, and dikes and apophyses, presumably radiating from these main masses, penetrate the greenstones for a considerable distance (cf. the Upper Quinnesec Fall, Horse Race, and region just north of Marquette). Now, the composition of these acid rocks is such that they resist chemical alteration much more successfully than those of a more basic character. Hence we should

[1] Geol. Wisconsin, vol. 3, p. 475.

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expect to find their distinctively eruptive features, such as dike-form, line of contact, original structure, etc., much better preserved. This is the case, and yet these eruptive rocks often present phenomena of secondary foliation quite identical with those seen in the greenstones.

Near the southern end of the Brook Section, just west of Marquette, this intrusive granite is filled with fragments of the surrounding schist which it tore off while yet in a molten state. At the lower end of the Horse Race Rapid, on the Menominee River, the acid dikes show a marked diminution in the size of the grain toward the dike walls, a structure eminently characteristic of rocks which have crystallized in fissures. Near Upper Quinnesec Falls also was discovered a rock closely resembling a granitic hornfels (No. 11064). But in spite of all the evidence that the acid rocks are eruptive, their dikes, for the most part, follow the strike of those through which they break, since this is the line of least resistance, while many of them have a perfect foliation and even a gneissic structure. What we may regard as satisfactory proof that this foliation is a secondary feature may be seen at the head of the Horse Race, where it conforms to the general strike of the surrounding greenstones, even where this does not coincide, as is exceptionally the case, with the sides of the acid band (see p. 115). A similar structure has been observed by Prof. Ch. E. Weiss, of Berlin, near Thal, in Thuringia;[1] and, like the present case, it may be regarded as certain evidence that a schistose or even a banded structure may be developed in acid dikes by secondary causes, independent of their own direction, but conformable with the strike of the surrounding rocks.

Microscopical evidence.—The most convincing proof that the rocks of the Menominee and Marquette greenstone areas are of igneous origin is not to be derived, however, from their field relations, but rather from their microscopical structure. It is true that there are many cases where rocks of widely dissimilar origin resemble one another so closely that not even the minutest study of their internal structure is able to distinguish them with certainty; nevertheless there are in other cases well marked peculiarities of structure which may be regarded as unfailing indications that the rock possessing them has crystallized out of a molten magma.

An explanation for these facts is not difficult to find. The original structures of clastic and igneous rocks are characteristic and essentially distinct. Where these remain there is no danger of confusion. In the process of metamorphism, however, there is a constant tendency to obliterate the original features and to substitute for them certain secondary features. But these latter depend altogether upon the chemical constitution of the mass and the nature of the metamorphosing forces, and are independent of both the mineral composition and the structure of the original rock. Hence it is that rocks fundamentally distinct in

[1] Petrographische Beiträge aus dem nördlichen Thüringer Walde. Jahrbuch preuss. geol. Landesanstalt für 1883, pp. 213–237. Berlin, 1884.

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both origin and structure grow more and more alike when subject to metamorphism. They may finally become indistinguishable and thus their life histories may be lost, but so long as any trace of the original structure is recognizable it may be relied upon as a safe guide.

It is, therefore, a matter of prime importance in petrography to be thoroughly acquainted with original rock structures, and to understand their significance. As a rule, those found in igneous rocks are more unmistakable than those which characterize clastic deposits. For instance, universal observation, together with numerous synthetical experiments in the laboratory, has shown that the peculiar divergent radial structure, known as the "ophitic" or "diabase" structure, is always the product of crystallization from a molten mass of certain basic rocks. No single observation has ever been made to indicate that this structure can originate in a sediment or by any metamorphism of a sediment; hence, we are justified, when we encounter the "ophitic" structure in a rock (no matter how much it may otherwise resemble a sedimentary deposit) in assuming that it is of igneous origin. Now, precisely this characteristic structure is what we do meet most frequently in the greenstones of both the Menominee and the Marquette area. Nor is it alone in the most massive and apparently least altered specimens that it is found; often the most perfectly schistose of these greenstones disclose it, and that, too, where none of the mineral components have escaped complete alteration.

Other structures, scarcely less typical of an igneous origin are also encountered in other of the Marquette and Menominee rocks. Some of these are: *porphyritic structure*, with well defined crystals and even a zonal growth; *micropegmatite and granophyre structure*, in granite, diorite and diabase; *poicilitic structure*, shown by the hornblende in the diorite porphyry at Lower Quinnesec Falls. The skeleton forms of the acicular feldspar crystals, still recognizable in the aphanitic greenstones of the Upper Twin Fall, as well as in those of the southern Marquette and Negaunee areas, are also strongly indicative of igneous, and perhaps also of glassy rocks.

The evidence of eruptive origin afforded by the present mineral components of the Marquette and Menominee rocks is not so satisfactory as that based on their structure. Nor is this different from what we should expect. Chemical metamorphism precedes structural metamorphism. Instances are frequent in both regions of the disappearance of every original mineral, while the structure remains intact. If we except the comparatively recent and unaltered diabases near Marquette, pyroxene—that most characteristic of volcanic minerals—was hardly ever encountered except in the gabbro at Sturgeon Falls. We can, however, assert with certainty that it was once present in many other rocks, where it is now represented by the pale green hornblende into which it so readily passes. Other species typical of igneous rocks, such as lath-

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shaped labradorite crystals and ilmenite fringed with leucoxene, on the other hand, are still met with in abundance.

With such evidence that the greenstones and associated acid rocks of the Menominee and Marquette regions are igneous in their origin, we may next inquire as to how many different types may still with certainty be recognized among them. In this section, whose effort it is to reconstruct the original form of the greenstones, no reference will be made to the secondary or metamorphic rock-types.

DIFFERENT ORIGINAL ROCK-TYPES.

BASIC ROCKS.

Olivine Gabbro.—This type, containing abundant and perfectly crystallized olivine, was found only in the northern area above Negaunee; (See Chap. V, p. 180); and even here under circumstances which left doubt as to whether the exposure was in situ, or a part of a huge, buried glacial bowlder.

Gabbro.—The only undoubted representatives of this type, i. e., granular aggregates of allotriomorphic diallage and plagioclase, were found at Sturgeon Falls on the Menominee River. Their diallage is of an unusually pale color and, like the whole rock, remarkably poor in iron, (cf. analysis on p. 76.) Their feldspar is almost wholly changed to saussurite. The rock exposed near the Eureka shaft, two miles west of Marquette, appears once to have belonged to this same type (p. 70); while the granular diorites so common at the Quinnesec Falls, although they now contain only pale green hornblende and no diallage, agree so closely with the Sturgeon Falls rock in appearance, structure, and chemical composition, that it is very probable that they were once gabbros also (pp. 86, 102).

Diabase.—This is by far the most common rock-type and it is found in every variety and stage of alteration.

An unaltered olivine diabase is the youngest rock of the Marquette area. It intersects all the other greenstones as well as the granite, as may be seen at the mouth of Dead River, besides occurring in interbedded sheets in the iron bearing series itself. It forms the great dike which terminates at Lighthouse Point, as well as many other smaller ones exposed in the Brook Section, in the northern area and at other localities. As the olivine is the first of all minerals to disappear, this type can, of course, be recognized only in the freshest specimens.

It is not always possible to say positively whether the quartz in the diabase is an original or a secondary constituent. The former, however, is probably the case in certain very fresh specimens and where, as in No. 11675 from the great dike, and No. 11646 from Front street, Marquette, it is present as a micropegmatitic intergrowth with the feldspar (p. 141).

No non-olivinitic diabase was discovered in a perfectly fresh state, but this type is assumed for many occurrences in which alteration is more or

less advanced. Such an assumption must, however, be doubtful, since any original olivine would have been the first mineral to disappear.

Diabase Porphyry.—It is now impossible to say whether the porphyritic greenstones occurring at the western end of the ridge below the Lower Quinnesec Falls once belonged to this type or not. If they did, they contained considerable original brown hornblende as an accessory constituent; but it seems more probable that these rocks were diorites.

Glassy Diabase and Melaphyre.—From the sides of the unaltered diabase dikes, glassy and half glassy rocks were obtained, which, of course, represent only a local facies of the main mass, due to more rapid cooling. They contain incomplete and skeleton forms of the minerals which were the first to crystallize, and in this respect they closely resemble some of the aphanitic greenstones of the southern Marquette and Negaunee areas. Indeed, one of these half glassy rocks from the edge of a much altered dike in the Brook Section, near Marquette (No. 11680, see p. 144), is quite identical with a certain widespread variety of the fine grained greenstones, and gives perhaps the clew for the deciphering of their original form (cf. p. 163).

Diorite.—The readiness with which the pyroxene of eruptive rocks passes over into a corresponding amphibole, makes the number of diorites among the Menominee and Marquette greenstones appear much larger than it really is. A majority of these are undoubtedly of secondary origin, having been derived from pyroxene rocks. Nevertheless, others of them, in which the secondary hornblende can be traced back into a compact brown variety of the same mineral, must be regarded as true diorites, unless we make the assumption that pyroxene has passed by paramorphism first into basaltic, and subsequently into fibrous green hornblende. The origin of other of the dioritic greenstones must always remain uncertain. Even at the risk of including some rocks of secondary origin, the principal dioritic types may be enumerated as follows: *Gabbro type*—light colored, granular rocks, like those forming the barrier at Upper Quinnesec Falls; these so closely resemble the Sturgeon Falls gabbro (even down to the orthopinacoidal parting of their hornblende) that there is strong reason to believe that they have been derived from a similar rock. *Coarse grained diorite* of the Horse Race, with idiomorphic feldspar and a pale green hornblende, which, though itself secondary, has probably been formed from a compact variety of the same species. *Granular diorite*, like No. 11175 from Four-Foot Falls and several dike-rocks in the Negaunee and Northern areas. *Quartz diorite*, like the Picnic Island rock and No. 11831, from the Northern area, west of Marquette. (See Plate IX, fig. 2.) Both of these are perhaps more properly amphibole granites, although the relative proportions of their orthoclase and triclinic feldspar leaves this in doubt. The so-called "epidiorites" are undoubtedly of secondary origin, and have been derived generally from augitic rocks.

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Diorite Porphyry.—The rocks containing large poicilitic hornblende crystals, collected from the western end of the ridge below the Little Quinnesec Falls, which have already been mentioned under the head of Diabase Porphyry, although they should perhaps receive the above designation.

Tuffs.—The schistose, banded greenstones which compose so large a part of the northern Marquette area are found to be best explained as tuff deposits of the basic eruptives which accompany them.

ACID ROCKS.

Granite.—Each of the greenstone areas is bounded on both the north and south by a large mass of granite. This rock is a typical *granitite* as can be best seen from the specimens collected south of the Horse Race in the Menominee Valley and north of the Marquette greenstone belt. *Muscovite granite* occurs in some of the bosses near Marquette, notably at the so called "gold mine" near Pine street. *Amphibole granite* is possibly represented in the specimens from Picnic Islands and the Northern area which have already been mentioned under the head of Quartz Diorite, although they appear to occupy a position midway between these two types.

Granite Porphyry and Quartz Porphyry are the forms assumed by the granite where it penetrates the greenstones in dikes or apophyses. They are abundant in both areas and are united by a continuous series of transitional forms. These rocks are among the most interesting ones anywhere met with on account of the perfection with which they show the effects of dynamic action. By either stretching or compression they are changed into Augen gneiss or schistose porphyry, both of which retain in their microscopic structure very plain evidence of the manner in which they were produced.

ORIGINAL MINERAL CONSTITUENTS.

Orthoclase occurs in all the acid rocks—granites, and porphyries; in some of the fragmental rock, as, for instance, those near Iron Mountain and in the stretched tuffs on the Carp River north of Teal Lake, and probably in the Picnic Island rock north of Marquette.

Microcline.—It is doubtful whether this form of potash feldspar is ever original. In some cases at least it is certainly the result of intense dynamic action on rocks already solid.

Oligoclase is, in all probability, the species of striated feldspar occurring in the granites.

Labradorite is the prevailing original feldspar in all the greenstones, as it is in the unaltered diabases occuring near Marquette.

Quartz is an abundant component of all the acid types; and it occurs also in both diorites and diabases, although it is here not always possible to distinguish between what is original and what is secondary.

Muscovite seems to exist in one or two granites as a primary component, but in the majority of cases it is a derivative of the orthoclase.

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Biotite is abundant in the granites. It is also present in the diorites, especially in those from the Horse Race Rapid, although here it may be secondarily developed out of the hornblende. In the diabase it is sometimes seen forming a border around the ilmenite.

Hornblende.—Compact brown, or basaltic hornblende is common in very many of the greenstones, though mostly as remnants of crystals which have become partly green or fibrous. It is also present in the Sturgeon Falls gabbro and in the Marquette olivine diabase. Compact green hornblende is also a very common mineral in the greenstones, but it impossible to tell to how great a degree this may be of secondary origin.

Diallage of a very pale color and very poor in iron is abundant in the gabbro of Sturgeon Falls. (See Pl. VIII, fig. 1.)

Augite of the ordinary kind, having a reddish brown color in transmitted light, is an essential ingredient of all the fresher diabases; and often exists as a core in the center of partially uralitized crystals.

Olivine, in fresh and perfectly formed crystals, was found in the olivine gabbro of doubtful origin which occurred in the Northern area above Negaunee. It also once formed a component of the younger diabases near Marquette, although it is now so altered to serpentine as to be only recognizable by its form.

Zircon is abundant in nearly all the acid rocks, and is present in the sediments near Iron Mountain in the Menominee valley. (No. 11113.)

Apatite is universal in all the rocks which have not been sufficiently altered to obscure it.

Tourmaline is common in the more acid rocks. It may be best seen in the granite and acid dikes near the Horse Race and Upper Quinnesec Falls. It is also present in the sediments exposed near Iron Mountain and Four-Foot Falls, as well as in the hornfels (No. 11064.)

Sphene occurs in both granite and diorite, especially in association with hornblende. In some instances it seems to have been derived from the alteration of ilmenite.

Orthite (*Allanite*) is present in certain granites, both near the Horse Race and in the Northern area above Negaunee.

Ilmenite and Magnetite.—The opaque iron oxide minerals are present in all the rocks in their usual abundance. Ilmenite is the most frequent, especially in the greenstones, but magnetite is also present.

CONDITIONS UNDER WHICH THE GREENSTONES WERE FORMED.

There is considerable evidence to show that the greenstones, both of the Menominee and the Marquette region, solidified at the surface, under subaerial or subaqueous conditions.

In the Menominee Valley this evidence consists (1) of the fine texture of the rocks; and (2) of the alternation of bands of different types, which probably in their original position represented successive flows. Fineness of grain is universal in the Menominee greenstones, and we may be certain that it was a primary feature in spite of the extensive alter-

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ation of these rocks. It is especially noticeable in the case of the gabbro, which is almost always a coarse grained rock when it has solidified at any depth. The succession of massive beds, like the pale gabbros and the dark diabases seen at Lower Quinnesec Falls, are difficult to account for except by supposing that they were once horizontal sheets which flowed one over another and which were subsequently elevated into their present nearly vertical position. Traces of tuff material are not as distinct here as in the Marquette region, although indications of their existence are by no means wanting. We might reasonably expect that any original scoriaceous or amygdaloidal structure would have disappeared in the course of the profound chemical changes through which these greenstones have passed.

In the Marquette area proof of the superficial origin of the greenstones may be found (1) in the fineness of grain, and (2) in the fragmental detritus or tuff, such as would accompany volcanic action. The so called "aphanitic greenstones," which play so important a role in the southern Marquette and Negaunee districts, have traces of a structure like that of a porphyrite or melaphyre (see Pl. X, fig. 2). At least there are incomplete forms of feldspar crystals apparently imbedded in a groundmass which might easily have originated from the devitrification and decomposition of a cryptocrystalline or even glassy base. The finely banded greenstone schists occupying the northern portion of the Marquette belt present such strong evidence of stratification and such peculiarities of microscopic structure (see Pl XVI, fig. 1) that they are best explained as tuff deposits belonging to the massive basic rocks. The presence of fragmental material of this kind, of course, strongly indicates surface origin for all these greenstones. Still other signs point in the same direction. At least one well marked specimen of amygdaloidal structure (No. 11746) was found near Baldwin's Kilns, but in the present highly altered condition of these rocks it can only occasion surprise that even this was preserved.

MACROSTRUCTURAL METAMORPHISM OF THE MENOMINEE AND MARQUETTE MASSIVE ROCKS.

This embraces all modifications in the structure of the massive rocks produced by dynamic agencies and plainly visible to the unaided eye. Such changes consist for the most part in the production of a banding, foliation, or schistose structure, which tend to make the eruptive rocks resemble stratified deposits. They are a secondary feature and must be correlated with the slaty cleavage, not with the original bedding of sediments.

In the process of upheaval and folding rocks may be subjected to great compression, with more or less attendant shearing or faulting, or the reverse may be true and a tension result. In the first case foliation is produced; in the second, the phenomena of stretching.

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MACROSTRUCTURAL METAMORPHISM THROUGH COMPRESSION, FAULTING, OR CRUSHING.

Simple compression.—There seems to be no doubt that a foliation or slaty cleavage may be produced by pressure in massive as well as in stratified rocks. This cleavage is developed in all cases at right angles to the direction of the pressure. It is particularly frequent in such basic eruptive rocks as, by their chemical composition, are more subject to alteration. In these the secondary development of such cleavable minerals as chlorite, hornblende, sericite, and biotite, which are given a parallel arrangement by crystallizing under pressure, strongly conduces to the production of a schistose structure. The pressure accelerates the chemical action, and may in this way develop a schistose out of a massive rock without movement in the mass.

A very general feature in the foliated greenstones of both the Menominee and Marquette regions is their tendency to cleave parallel to a line instead of parallel to a plane; in other words, they possess a dip but no decided strike. The rock then breaks with readiness into long rhomboidal prisms with almost any angle, but is severed with difficulty at right angles to this axis of foliation. Such a structure would seem to indicate the action of an unequal or shifting pressure. Examples of this method of parting are very common, especially at Sturgeon, Lower Quinnesec, and Twin Falls, in the Menominee Valley, and in the southern portion of the Marquette greenstone area.

One of the best proofs of the secondary origin through dynamic agency of the greenstone foliation is the fact, noticed by Major Brooks, that at Four-Foot Falls this is parallel to the slaty cleavage, but not to the bedding of adjoining sediments.

Another method by which a schistose structure is produced in the Menominee greenstones, is the gradual flattening of the rhomboidal prisms which are formed by the intersection of two sets of joint-planes. This is illustrated by Figs. 20, 21, and 22, on page 128. These prisms seem to be elongated by the action of intense pressure into a series of interlacing lenses. A sort of "Flaser" structure is thus produced which, in its extreme development, becomes a well characterized schistose structure. Even in the broadest of these prisms a latent cleavage is often noticeable parallel to their longest diagonal, always following the general strike of the adjoining rocks. This structure, which I have designated as rhomboidal, or diamond parting, may best be seen at the Twin Falls or at the upper end of the great greenstone ridge below Lower Quinnesec Falls.

Faulting or crushing.—A schistose structure is always produced in massive rocks along lines where a great tension has been relieved by breaking and a consequent displacement. Movement of this kind within a solid mass, must be accompanied by more or less intense crushing, and this allows increased circulation and hence of the rapid production of secondary crystallizations. Admirable instances of this phenom-

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enon abound in both the Menominee and Marquette greenstones. At the Sturgeon Falls, along the basin just below Lower Quinnesec Falls, below the Horse Race, at the Twin Falls, at the foot of Arch street, Marquette, and at many other localities within this area, it may be seen with remarkable distinctness. The exact effect of the crushing on the original mineral constituents is visible only under the microscope and hence will be considered in the succeeding chapter; but any one who will carefully examine any of the above named localities can not fail to be convinced of the continuity and original identity of the massive and schistose rocks.

Both the width of these schistose bands and the intensity of the crushing which they exhibit vary widely in different cases. Their direction almost always coincides with the general strike, although at Upper Twin Falls such bands were observed to have a different direction. (See p. 132.)

This pulverization of the rock is accompanied by greatly increased chemical action (except in the notable instance of the feldspar) and the abundant production of chlorite. Such crushed bands possess a more or less perfect lenticular or "Flaser" structure, which passes gradually into a lamination where the action has been more intense. This is almost entirely due to the parallel arrangement of the secondary chlorite scales, so that we have a basic eruptive rock developing into a typical chlorite schist.

Excellent examples of a massive, though much altered greenstone fraying out into a chlorite schist by the action of a shearing force along lines of slight displacement, were found at lower Twin Falls, and are illustrated in Figs. 23 and 24. (See pp. 129, 130.)

The great mechanical force generated in the course of orographic movements, aided by chemical action, sometimes develops schistose bands in massive rocks, which wind around and encircle compact cores. These are spheroidal or lenticular in shape, and seem for some unknown reason to have better resisted the metamorphosing influences. A fine example of this kind may be seen on the Wisconsin side of the Menominee River, just at the foot of Lower Quinnesec Falls. It is represented by specimens Nos. 11017 to 11020, described on p. 93. Other examples of the same kind occur in the railroad cut near Front street, Marquette.

This last described structure has much in common with the spheroidal or lenticular parting observed in the aphanitic greenstones of the southern Marquette and Negaunee areas. (See Figs. 26 and 27, pp. 166, 177.) Near the mouth of Whetstone Brook; in the neighborhood of Baldwin's Kilns, and between Teal Lake and the Carp River, we see the fine-grained greenstones broken up into circular or oval areas, which are separated by a finer schistose matrix. This structure is common through the Northwest, and has been termed by the Canadian geologists "concretionary trap." It is, however, in no sense really concre-

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tionary, but must be ascribed either to contraction which frequently produces a perlitic structure or spheroidal parting in volcanic rocks, or to a mechanical brecciation and rubbing together of the disjointed fragments, as was found by Rothpletz to be the case in similar greenstone schists of Saxony. (See p. 167.)

MACROSTRUCTURAL METAMORPHISM THROUGH STRETCHING.

The effect of stretching upon rock masses has only recently come to engage the attention of geologists. It is evident that in the process of the upheaval or folding some parts of the mass must be strained, while other parts are compressed. As Heim first pointed out, such a tension is relieved sometimes with and sometimes without a visible rupture. Both of these methods are well illustrated in the massive rocks of the Menominee and Marquette regions.

In the first case we find the formation of irregular, ragged seams, which Heim has designated as gaping rents ("klaffende Risse"), and which I have termed "cross-gashes," from their being torn open in a direction perpendicular to that in which the tension was exerted. They are, therefore, approximately parallel, and may produce a rough sort of schistose structure. These seams sometimes remain open, but are sometimes filled with secondary crystallizations, like quartz, calcite, or chlorite, often with epidote. They are best exhibited in the great greenstone ridge which extends along the river's left bank below Lower Quinnesec Falls. Their appearance, as far as it can be shown in a hand-specimen, is represented in Fig. 10, p. 81.

The manner in which the round cores of the spheroidally parted greenstones in some cases have been drawn out into interlacing lenses, has already been noted (p. 177).

Stretching action may sometimes produce a banding in massive rocks. This is especially the case with acid types, like granite and quartz porphyry. Examples of this are to be found among the acid dikes near the Horse Race and in the vicinity of Marquette, but the most indubitable evidence of stretching in these rocks is contained in their microscopic structure, and must therefore be reserved for description in the following section.

MICROSTRUCTURAL METAMORPHISM OF THE MENOMINEE AND MARQUETTE MASSIVE ROCKS.

Where profound mechanical and chemical changes have gone on simultaneously in rock masses, the final product may be wholly different from the original starting point. Sedimentary and eruptive rocks seem to approach each other more and more nearly, the longer they are exposed to the same metamorphosing influences. In many cases the derivation of certain schists can never be definitely settled; in other cases, however, where the field evidence is insufficient to decide, the micro-

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scope may yield reliable data for settling the origin of doubtful crystalline schists. Characteristic minerals or structures may often be detected under the microscope after every original feature visible to the unaided eye has been obliterated.

In stating the results of dynamic action observed with a microscope in the Lake Superior rocks, we may speak first of the effect upon individual minerals, and then of new structures produced. As a rule, those minerals and rocks which are hardest and most brittle are found to exhibit these mechanical effects most perfectly.

EFFECTS OF DYNAMIC ACTION ON INDIVIDUAL MINERALS.

Quartz.—We find corroborative evidence of the fact stated by others that quartz is frequently more sensitive to pressure than feldspar. In the quartz porphyry, No. 11707, for instance (see Pl. XV, fig. 2), which has undergone a violent stretching, the feldspar crystals apparently exhibit no resultant phenomena, if we except the presence in their center of microcline as a possible product of strain; the quartz crystals, on the other hand, show an unusual amount of deformation. In some cases they are pinched out into pear or spindle shaped areas with an undulatory extinction; while in other cases they are much more elongated, but show that this result has not been reached without a crushing and displacement of their original substance (granulation). The fragments are converted into a mosaic of interlocking grains by the readiness with which silica is dissolved and deposited. Quartz that is more or less optically disturbed is almost universal in the acid rocks examined, showing that hardly any of them have been entirely free from mechanical strains. That the quartz grains in the granite No. 11104 are not all original is proved by the little tourmaline crystal, which is fractured and faulted at the junction of two of them, as depicted in Fig. 13, p. 112.

Feldspar.—The first effect of strain on feldspar is to produce an undulatory extinction. This cannot, however, be carried as far as it is in quartz, because the tension is here able to relieve itself by molecular movements and the consequent formation of twinning lamellæ. Several cases were encountered where the gridiron or microcline structure appears to have been secondarily developed in a potash feldspar by this means, as in the granites Nos. 11104 and 11710 and in the schistose quartz porphyry No. 11707. Such a production of secondary or strain lamellæ in the triclinic feldspars is by no means unusual.

Where the mechanical action is too intense to produce mere optical disturbance or molecular gliding without rupture, the force of cohesion is entirely overcome and the feldspar is fissured or crushed. In case the force is exerted as a tension, the fragments thus formed are separated, and the spaces between them are filled with secondary crystallizations, especially chlorite. In other cases the fragments are merely faulted against one another. Such examples of stretched and faulted feldspar are very abundant in the schistose greenstones and acid rocks

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of the Menominee and Marquette districts. It is generally possible to recognize what fragments once belonged together, as may be seen by an inspection of Pl. IX, fig. 2, Pl. XI, fig. 2, Pl. XIV, figs. 1 and 2, and Fig. 11 on p. 105. Even in very schistose rocks, which are in other respects chemically much altered, these broken feldspars are, as a rule, unexpectedly fresh; a fact which will receive particular attention in the succeeding section.

If the mechanical force is still greater, a pulverizing or granulation of the feldspar ensues. This is always accompanied by chemical action, consisting of more or less complete solution and recrystallization. In this way the substance is molded into new forms, which accord better with the existing strains.

Such a partial granulation of a large porphyritic feldspar crystal, producing one of the lenticular "Augen" of the metamorphic gneisses of the Horse Race, is shown in Pl. XV, fig. 1.

In the process of feldspar granulation the calcium is frequently removed, and the secondary mosaic is largely composed of albite, as was first shown by Lossen.

Pyroxene.—Diallage is very subject to mechanical deformation. On account of its relative softness and flexibility this consists mostly of the bending or twisting of the crystals, or in the occasional production of twinning lamellæ. These phenomena may be well seen in the almost colorless diallage of the Sturgeon Falls gabbro. Pyroxene exists in no other of the rocks examined except in those which are too young to show any effects whatever of dynamic action.

Hornblende.—Certainly in a large majority and possibly in all the rocks which I have studied from northern Michigan, hornblende is a secondary product; since, then, it is a result of metamorphism, it is not strange that we rarely see in it the effects of that mechanical action which caused the metamorphism.

Mica.—On account of its flexibility mica, like diallage, would be well fitted to exhibit mechanical phenomena; but the fact that, like the hornblende, it is mostly a secondary mineral in those rocks to which we have here devoted our attention, prevents such deformations from being common.

Zircon, Tourmaline, etc.—These minute products of the first crystallization in the rock are often found to be broken or faulted by mechanical action, as is shown in Fig. 13, p. 112, and Fig. 18, p. 122.

Ilmenite.—The iron minerals, on account of their opacity, of course can exhibit no optical disturbance, but their grains are frequently torn apart just like the feldspar crystals. This has been described in numerous instances, and it is represented in Pl. XI, fig. 2.

NEW STRUCTURES PRODUCED BY DYNAMIC ACTION.

Whenever the crushing of rocks by dynamic agencies is accompanied, as it almost always is, by chemical action and the production of new minerals, these must arrange themselves in accordance with the exist-

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ing strains. These secondary minerals are such as themselves possess a very perfect cleavage; their production, therefore, under circumstances of uniform and continued strain, will naturally impart a foliation to the originally massive rock. Nor is this all. The relief of the strain and the consequent crushing of the rock will take place along certain planes much more completely than along others; hence in these planes the secondary minerals will be more abundant, and a banding of a once homogeneous rock may result.

The final structures produced in this manner depend not altogether upon the force exerted, but also upon the primary structure of the rock.

The rubbing together of individual crystal grains, the adhesion between which is weaker than their own internal cohesion, may produce a pulverizing only around the edge, when the force is not too intense. This phenomenon, to which Professor Kjerulf has applied the term "peripheral granulation" (randliche Kataklase),[1] may bring about a sort of pseudo-porphyritic structure, in which, however the porphyritic crystals are only the larger remnants of the former grains without a crystal form of their own; or, if the crushing has been less, the grains may appear to be held together by a fine granular cement, like the stones of a wall by their mortar. Hence Professor Törnebohm has spoken of this as the "mortar structure" (Mörtel Structur).[2] Many admirable examples of these structures are to be seen in the Menominee and Marquette rocks, especially in those of an acid character. There may be particularly mentioned the granite from the great area south of the Menominee, No. 11104; Nos. 11189 and 11190 from acid dikes at the Horse Race; Nos. 11678 and 11710 from the Brook Section, near Marquette. In the first instance, a distinct micropegmatitic structure is a noticeable feature of the granular cement.

If the original structure of the rock was porphyritic instead of granitic, we find corresponding differences in the result. The groundmass is made schistose by the development out of its feldspar of sericite or chlorite. The porphyritic crystals are more or less granulated, but the secondary mosaic thus formed is often coarser in grain than the groundmass. This is arranged around the remnant of the original crystal in a lenticular area known as the "eye," or "Auge," in rocks called by the Germans, on account of this structure, Augengneiss. (See Pl. XV, fig. 1.) Unusually beautiful examples of this kind are to be found among the acid dikes along the shores of the Horse Race—especially specimens numbered 11184 and 11196. In some of the schists which have been derived from the Sturgeon Falls gabbros a similar structure is present.

Where secondary micaceous minerals have been developed in sinuous bands which interlace and twine about abundant oval cores, a lenticu-

[1] Grundfjeldsprofilet ved Mjøsens sydende. Nyt Mag. for Naturvidenskaberne, vol. 29, p. 215, 1885. (Neues Jahrbuch für Mineral., 1886, vol. 2, Referate, p. 244.)

[2] Några ord om granit och gneis. Geol. Fören. Stockholm Förhandl, vol. 5, pp. 233–248. (Neues Jahrbuch für Mineral., 1881, vol. 2, Referate, p. 50.)

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lar structure is produced, in which there is no contrast between groundmass and porphyritic crystals. This is called by the Germans "Flaser" structure, a term which may advantageously be transferred to the English. It is often the case that a structure of this kind is so fine as to be visible only under the microscope, when the designation "microflaser structure" is applicable. Examples of this lenticular interlacing are abundant in the schistose greenstones of northern Michigan. It is especially typical in the Sturgeon Falls schists, and in those at Lower Quinnesec Falls; it may also be well seen in the granite at the mouth of the Dead River, north of Marquette.

In rocks that have been subjected to a great tension, a peculiar microscopical structure has been developed, caused by the rupture of the original crystals and a pulling apart of their fragments. Between these chlorite is formed, the scales of which are parallel to one another and to the direction of the stretching. This chlorite appears to have resulted from the recrystallization of the substance of the original bisilicates, since no trace of these now remains, although the broken feldspar is always remarkably fresh. There must be something in the dynamic action of an intense tension particularly conducive to the formation of this chlorite, for exactly this modification of this mineral was not encountered in rocks produced in any other way. Its presence, of course, brings out a decided schistose structure. Excellent examples of this phase of structural metamorphism abound in the Menominee and Marquette greenstones, although I do not know that anything exactly like it (particularly when taken in connection with the remarkable freedom of the broken feldspar from all signs of chemical change) has ever been described before. It is illustrated in Pl. XI, fig. 2. The widely different results produced in the same greenstone by chemical action alone on the one hand, and by this agency combined with stretching on the other, are shown in Pl. IX, figs. 1 and 2. The same thing is admirably seen in two specimens (Nos. 11651 and 11652) from the Cleveland ore dock in Marquette. (See p. 168.)

If we could desire any more certain proof that these "stretching structures" are of secondary origin, developed in an already solid rock, we should find it in No. 11803 (Pl. XIV, fig. 2). Here the porphyritic feldspar crystals lie in the groundmass at every conceivable angle, showing that at the time they were formed there was no force to affect their orientation. Their breaking and tearing asunder, however, in every case, has taken place in the direction of the foliation or stretching, without the least reference to the position of the feldspar crystal itself.

MINERALOGICAL (CHEMICAL) METAMORPHISM OF THE MENOMINEE AND MARQUETTE ROCKS.

Chemical alteration may go on to almost any extent in massive rocks, unattended by any mechanical deformation; and yet certain chemical changes in rock-forming minerals seem to be dependent upon the phys-

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ical conditions produced by great orographic strains. It is easy to understand how the crushing of a rock should, as a rule, accelerate chemical activity by increasing the circulation and possibly by raising the temperature by friction; but more than this, we find that of several different alterations to which a given mineral is subject, certain ones are never found except in those regions where dynamic action has been intense.

It is true that the same secondary mineral may be produced in different ways. It may result from the same original mineral under different conditions, or from different minerals under the same conditions, or from different minerals under different conditions. It may also sometimes be derived from a single substance, and sometimes from a reaction between two or more substances. On account of the small number of elements which enter into the composition of rock-forming minerals, their physical differences are due mostly to the different proportions in which these elements are combined. Very slight variation in conditions may modify these proportions and so produce one mineral or another. Even in exactly the same chemical compound, what may be a stable state under one set of conditions, may be an unstable state under another set. So delicate is this adjustment that the secondary minerals produced in a given case depend not merely upon the chemical composition of the original rock or of its constituents, but even to a greater degree upon the physical conditions obtaining at the time of their formation. Thus with every change of these, one generation of secondary minerals may give place to another.

Such a succession of alterations, each dependent upon its own set of conditions, tends to obscure the life history of a rock mass; and yet, in spite of its complexity, this study is full of promise. It is generally possible to separate the products of metamorphism proper from those of weathering, as described in Chapter I (see p. 36). All the massive rocks of the Menominee and Marquette regions offer admirable opportunity for the study of the first of these alterations, while the more basic types often present the subsequent effects of weathering.

In reviewing and summing up the results of chemical alteration already described at length, it will be advantageous first to enumerate the minerals of secondary origin, stating briefly the circumstances under which each was probably formed, and second to trace out the different phases of alteration to which each of the more important original constituents has been subjected.

SECONDARY MINERALS AND THEIR ORIGIN.

PRODUCTS OF METAMORPHISM.

Feldspar.—This mineral is not common as a secondary product except in the form of albite, which as Lossen has shown (see Chap. I. p. 60) is a very characteristic result of dynamic metamorphism. In the Sturgeon Falls gabbro albite is a common secondary mineral, both as

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the base of saussurite and in the form of clear, transparent veins. Here the twinning structure is not frequent, but it may be seen in some of the veins, as is shown in Fig. 4, p. 69. Albite in the form of a fine granular mosaic, with or without quartz also occurs in many of the altered diabases. Its substance is so clear and glassy as to leave no doubt about its being a secondary product.

Microcline as a secondary mineral is to be referred rather to the effect of pressure twinning than to chemical alteration.

Saussurite (Chapter I, p. 58) is not a simple mineral, but a mixture derived from the alteration of the lime-soda feldspars. It is abundant in the more basic rocks of the Menominee and Marquette regions—in the gabbros of Sturgeon Falls and in many diabases and diorites. The base is a clear, soda feldspar (albite) which contains zoisite needles, or more rarely epidote and colorless garnet. (No. 11189, p. 108.)

Zoisite occurs only as one of the constituents of saussurite above described. It is in the form of minute needles, without terminations, as shown in Figs. 5 and 6 (pp. 69, 70). These differ much in size, and between crossed nicols display dull bluish interference colors. When the zoisite needles are very small the saussurite is a gray opaque mass, which only the highest power of the microscope is able to resolve.

Garnet was observed only once, in minute colorless crystals, forming, along with epidote, one of the constitutents of the saussurite in specimen No. 11189. (see p. 108).

Quartz is a widespread secondary mineral. It often originates from the breaking up of the more acid feldspars, like orthoclase. It may also originate from the lime-soda feldspars. Primary and secondary quartz sometimes present an identical appearance. In some of the Lake Superior diabases quartz seems to be an original component, and in others of the more altered ones it is certainly of secondary origin. In a few intermediate cases its origin must always remain doubtful. Owing to the ease with which silica is transported in solution, that which is set free by the decomposition of the silicates is often entirely removed from the rock or is deposited in seams. In at least one instance a brown isotropic substance resembling opal was observed (the gabbro from Eureka Shaft near Marquette p. 170).

Hornblende.—Although there is reason for considering the hornblende in some of the Menominee and Marquette greenstones as a primary constituent, still there can be no doubt that this mineral is also the most important secondary component of these rocks. In a fibrous form as uralite, amianth, etc., hornblende is almost the sole representative of the former pyroxene in the more altered and schistose diabases, and the same mineral seems also to be the final metamorphic product of the compact hornblende in the diorites. Indeed, the schistose structure of these rocks is largely due to the production of fibrous hornblende and lamellar minerals of the mica type, and to their arrangement parallel to a single plane. The components of the secondary fibrous hornblende

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are mainly derived from some bisilicate, like pyroxene or compact hornblende, but its position is by no means confined to the area formerly occupied by these substances. On the contrary, the material shows a tendency to wander, and to develop amphibole needles along the cleavage cracks of the feldspar, as seen in Plate XII, fig. 2. This may even become filled with the hornblende, as in the epidiorite, No. 11663, from Pine street, Marquette, and the whole rock be finally reduced to a fine, felt-like mass, as shown in Plate IX, fig. 1.

Compact hornblende also, both brown and green, appears to have resulted extensively in the greenstones from the direct alteration or molecular rearrangement of pyroxene. Such a change has often been recorded, as stated in Chap. I. Indeed, the probability that much of the pyroxene of the original rocks has passed into fibrous green hornblende *through an intermediate stage of compact hornblende* has already been alluded to (p. 72). The brown or basaltic variety is to be found associated with the diallage of the Sturgeon Falls gabbro, as shown in Pl. VIII, figs. 1 and 2; also in the porphyritic rock from the western end of the "gabbro ridge," near Little Quinnesec Falls, on the Menominee. The compact green hornblende of Nos. 11176 and 11178, from the Four-Foot Fall, and of many of the Horse Race diorites, has precisely the form of diabasic augite; and in spite of its compact structure shows in its pale color and darker green border clear evidence of its secondary origin.[1] The pale compact hornblende of the barrier rock at Upper Quinnesec Falls (No. 11054) looks exactly like diallage,[2] and under the microscope its most exceptional orthopinacoidal parting bears testimony to its derivation from this mineral. (See p. 103.)

The manner in which the compact hornblende ravels out and becomes fibrous is often clearly seen in the Lake Superior greenstones, and is shown in Pl. XII, fig. 1, and in Fig. 19 on p. 126.

Epidote is a common metamorphic mineral, and appears almost always in small but well formed yellowish crystals. It sometimes forms one of the constituents of saussurite, but far less frequently than zoisite, as more iron is necessary for its genesis. In one case, No. 11091, the feldspar of a coarsely granular rock from the Horse Race, seems wholly changed to large individuals of epidote, while the pyroxene has given place to corresponding areas of a rather compact greenish hornblende (p. 108). In No. 11712, from the Brook Section, near Marquette, the change of the feldspar to epidote is less complete. Epidote more commonly results from the alteration (perhaps weathering) of some ferrous bisilicate. Here it is generally in association with bright green chlorite in the form of the characteristic aggregate described in Chap. I (p. 56). This is very common in many of the more altered greenstones of the regions studied. (See Pl. XI, fig 1.)

[1] See Pl. XII, fig. 2; and cf. Lossen: Erläut. zur. geol. Specialkarte von Preussen, Blatt Harzgerode, 1882, p. 81; and Williams' Bull. U. S. Geol. Survey, No. 28, Pl. I, fig. 2; Pl. II, fig. 1, 1886.

[2] cf. H. Credner: Neues Jahrbuch für Mineral., 1870, p. 972.

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Biotite originates under certain circumstances from hornblende. This is an alteration well known to mineralogists,[1] and may be admirably seen in several of the Horse Race diorites and in the curious amphibole granite, No. 11831, figured in Pl. XVI, fig. 2.

Muscovite, Sericite.—The potash micas hold a similar place in relation to orthoclase, as a product of dynamic metamorphism, that saussurite does to the lime-soda feldspars. In some specimens, as for instance in the granite No. 11089 from the Horse Race and in No. 11660 from the so-called gold mine near Pine street, Marquette, broad plates of typical muscovite are developed in the feldspar; generally, however, the alteration is due to the minute scales or curved foliæ called sericite. These two minerals are quite identical in composition and generally in origin, as has been explained in Chap. I. The development of sericite may be best studied in the schistose porphyries, which owe their cleavage to stretching. These are abundant in both the regions investigated, especially at Upper Quinnesec Falls (see Chap. III, and Pl. XIV, fig. 1) and near the city of Marquette (Chap. IV). While the production of sericite in the acid rocks is for the most part the result of intense dynamic action, it would seem as though it were especially liable to result, like certain varieties of chlorite (see below), when this force acted as a tension rather than as a compression.

Titanium minerals.—The metamorphosed eruptive rocks of the regions studied offer unusual opportunities for tracing the varied transformations of the titanium compounds. It is doubtful whether this element existed in the original rocks in any other form than titanic iron (ilmenite) or as a component of certain biotites. In the metamorphic rocks, however, titanium minerals are numerous and their origin can be traced to different sources. The probable derivation of rutile and magnetite from ilmenite may be seen in No. 11070, from Upper Quinnesec Falls (Pl XIII, fig. 2), and also in No. 11825, from northwest of Marquette (p. 184). The little "Thonschiefernadeln," shown in Fig. 12 (p. 106), seem also to have been derived from ilmenites. A sagenitic network of rutile produced by the alteration of biotite and the consequent freeing of titanic oxide is seen in No. 11113, from Iron Mountain; in No. 11672 from Marquette; and in No. 11738, from near Baldwin's Kilns, Negaunee.

Anatase, along with leucoxene, has resulted from the alteration of ilmenite in No. 11130, from Twin Falls (Fig. 26, p. 166) and in No. 11802, north of Negaunee, near the Carp River. Anatase seems also to have resulted from the decompositon of titaniferous biotite in Nos. 11050 and 11052, from near Upper Quinnesec Falls.

Sphene in the form of leucoxene is a universal result of the alteration of ilmenite in the metamorphosed diabases. In rare cases, like No. 11014, from Lower Quinnesec Falls, it is intimately associated with

[1] See J. Roth: Allgemeine undchemische Geologie, vol. 1, p. 333, 1879, and Inostranzeff: Metamorphosirte Gesteine im Gouvernment Olonez, 1879, p. 192.

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rutile, which may have been produced simultaneously with the alteration of the leucoxene, or have resulted from it. In other exceptional cases the product of the ilmenite appears with all the crystal form and physical properties of rock-forming sphene. Such an occurrence in No. 11189 from the Horse Race is shown in Pl. XIII, fig. 1; and another in No. 11831, from northwest of Marquette, in Pl. XVI, fig. 2.

The secondary minerals thus far enumerated are products of metamorphism proper, as distinguished from weathering; that is, they are highly crystalline, and have been produced under circumstances very different from those ordinarily prevailing at the earth's surface. Here the tendency is for the more crystalline and less soluble compounds to become more soluble through union with water and carbon dioxide. Hydration and carbonatization are therefore characteristic results of surface action upon rocks. They bring about their disintegration and decay, as purely metamorphic processes do not. Both metamorphism and weathering are very apparent in the eruptive masses of the Menominee and Marquette regions. The rocks of Keweenaw Point, on the other hand, show only the effects of weathering. In spite of their great antiquity they have not undergone metamorphism in the strict sense. Much younger rocks in disturbed areas are often found to be intensely metamorphosed, which clearly shows that something besides mere lapse of time is necessary to accomplish this change.[1]

PRODUCTS OF WEATHERING.

The secondary minerals in the Menominee and Marquette massive rocks which owe their existence to atmospheric action or weathering belong mainly to the following species: Chlorite, talc, serpentine, carbonates (calcite, dolomite, etc.), iron-hydroxide, and pyrite.

Chlorite is generally a product of weathering, but its origin is sometimes closely associated with dynamic agencies. For instance, it is a constant feature in the basic rocks which have been stretched (like sericite in the more acid ones), filling with its parallel folia the interstices between the broken and separated fragments, and thus imparting a degree of schistosity to the entire mass. (see Pl. XI, fig. 2.) The ordinary process of chloritization has been described in Chapter I, and frequently alluded to in the petrographical descriptions, since it is extremely common in the basic eruptives. If the original mineral was very poor in iron an almost colorless chlorite was the result, as in the Sturgeon Falls gabbro (Pl. VIII, fig. 2). In the highly ferruginous diabases, on the other hand, the chlorite has a deep green color and is often pleochroic. This is the "viridite" of the older authors, which is

[1] The efficiency of orographic movements to bring about this result has already been sufficiently emphasized. The observations of Lossen that similar changes may be produced by the contact action of large masses of intrusive granite have been briefly referred to in Chapter I. To what extent the enormous granite areas lying on both sides of the Marquette and Menominee greenstone belts may have been instrumental in effecting their mineralogical metamorphism must for the present be left undecided, inasmuch as no evidence directly bearing upon this question has as yet been collected.

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frequently associated with sharply defined epidote (secondary augite of Wichmann), as figured in Pl. XI, fig. 1. Chlorite seems to be the common effect of weathering upon pyroxene, hornblende, and biotite.

The peculiar variety of chlorite known as "helminth" in vermiform aggregates occurs imbedded in secondary quartz in some of the Sturgeon Falls gabbros, and is represented in Fig. 8 on p. 71.

Talc results in some cases from the alteration of hornblende, as observed by Tschermak,[1] Inostranzeff,[2] Becke,[3] and the writer.[4] This is not a common phenomenon in the Michigan greenstones, but some admirable examples were observed in the coarse grained diorites of the Horse Race above Upper Quinnesec Falls.

Serpentine.—The scarcity of olivine in the rocks examined makes the ordinary derivation of serpentine uncommon. This, however, does occur in some of the least altered diabases of Marquette. Indeed, serpentinization is almost the only effect of weathering noticeable in some specimens from the great dike of Lighthouse Point (olivine diabase), certain weakly polarizing fibers resulting from the change of hornblende appear to be serpentine, which, according to Rosenbusch,[5] frequently gives rise to this mineral. An instance of this may be seen in Nos. 11078 and 11191 from the Horse Race (p. 109).

Carbonates.—These most frequent products of weathering abound in the most altered greenstones, but they are nevertheless not unfrequently absent on account of the readiness with which these compounds are removed in solution. Calcite and dolomite are not microscopically distinguishable without a chemical reaction, but this is hardly necessary for most cases.

Iron-hydroxide and *Pyrite* are both iron compounds universally produced in basic rocks under ordinary atmospheric influences. The Michigan greenstones present no exception in the amount of these minerals which they contain.

PROGRESS OF ALTERATION IN THE ORIGINAL MINERALS.

Feldspar gives alteration products depending very largely upon its original composition, whether alkaline or calciferous. By far the most common change in the more basic rocks is to saussurite. This varies in different cases from a comparatively coarse grained zoisite aggregate to a dull gray, almost opaque mass which, even in the thinnest sections, is beyond the highest power of the microscope completely to resolve. The saussuritization may be often seen to have proceeded from the periphery of the feldspar crystal inward. In such cases a comparatively unaltered center remains, as in No. 11168 from Sturgeon Falls (Pl. VIII, fig. 2). Quite as frequent is the occurrence of a clear per-

[1] Tschermak's mineral. u. petrog. Mittheil., vol. 4, p. 65, 1876.
[2] Metamorphosirte Gesteine im Gouvernment Olonez, Leipzig, 1879, p. 167.
[3] Tschermak's mineral. u. petrog. Mittheil., vol. 4, 1882, pp. 339 and 349.
[4] Bull. U. S. Geol. Survey, No. 28, p. 58, 1886.
[5] Mikros. Physiog., 2d ed., vol. 2, p. 108.

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iphery around feldspar crystals which have been completely saussuritized. (See No. 11167 from Sturgeon Falls (Pl. VIII, fig. 1); No. 11054 from Upper Quinnesec Falls, and No. 11182 from the Horse Race.) The clear feldspar substance in such cases appears like a new crystallization rather than an unaltered survival of the original individual (cf. Fig. 4, p. 69).

The inverse ratio existing between the mechanical and the chemical action visible in the altered feldspars of the basic rocks has been often alluded to on pp. 88, 169. This seems to be the reverse of what might be expected, as well as of what is actually observed in the case of all the other constituents. It is, however, frequently the fact that, in a continuous rock mass, feldspar is most completely saussuritized which occurs in the least crushed portion, while the rock which is most broken, stretched, and foliated retains its feldspar fragments in a quite fresh and unaltered condition. That this fresh feldspar is not a new crystallization, is proved by the fact that fragments can often be seen to have once fitted together, as portions of one individual, before the crushing took place. Among many sections in which this phenomenon can be observed may be mentioned: The Sturgeon Falls gabbro; the rocks of the diorite ridge near the Lower Quinnesec Falls; Nos. 11004, 11010, 11019, and 11102 from just below the Lower Quinnesec Falls; Nos. 11054, 11073, and 11056 (see Fig. 11) from Upper Quinnesec Falls; No. 11179 from Four-Foot Falls, and Nos. 11651 and 11652 from the Cleveland ore dock in Marquette.

Such observations, made at many widely separated localities within the Menominee and Marquette greenstone areas, would at first thought seem to indicate that there is a reciprocal relation between the chemical and mechanical effects produced by great pressure. In other words, that the force which in the massive portion of the rock caused increased chemical action and alteration of the feldspar to saussurite, was expended, in another part, in the work of crushing. The fact, however, that the bisilicate constituents are more altered in the crushed bands than in the other part of the rockmass is opposed to such an explanation, and seems rather to indicate that the more ready alteration of these and the production of such minerals as fibrous hornblende, chlorite, and talc, formed a soft matrix which protected the feldspar from the further action of pressure and chemical action.

A totally different alteration from saussuritization is sometimes observed in the feldspars of the more basic eruptives. This consists of their change to green hornblende needles, and can of course occur only where a portion of the necessary elements is furnished by some bisilicate. These elements (i. e., magnesium and iron) wander along the cleavage cracks of the feldspar, causing the development of the needles as shown in Pl. XII, fig. 2. A very complete instance of this change is shown in the epidiorite, No. 11663, from Pine street, Marquette.

Still another alteration of the plagioclase is to epidote. This is com-

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plete in No. 11091 from the Horse Race, and partial in No. 11712 from the Brook Section, near Marquette.

While the lime feldspars change to zoisite, epidote, or hornblende, the alkaline feldspars show a corresponding tendency to pass into mica (sericite). This process is most commonly central, the periphery of a crystal remaining intact after the interior is completely altered, as may be seen in No. 11104, the granite from south of Upper Quinnesec Falls. This same specimen exhibits an interesting phase of the inverse ratio existing between the mechanical and the chemical action in the acid feldspar. Microcline seems to have been abundantly developed from orthoclase by pressure but while the orthoclase itself is sericitized, *the microcline never shows a trace of this change.*

Pyroxene is comparatively rare in the rocks studied, occurring only as diallage in the Sturgeon Falls gabbro, and as augite in the younger Marquette diabases; nevertheless, from the structure of many of the other rocks, we may affirm with certainty that they once contained pyroxene, and may hence trace the alterations which this mineral has undergone.

The most common, and indeed the almost universal change of the pyroxene in the Menominee and Marquette rocks is to hornblende. The compact brown hornblende in the Sturgeon Falls gabbro and in the porphyritic rocks from the west end of the ridge near Lower Quinnesec Falls, shows strong evidence of having originated from pyroxene, but this can not perhaps be regarded as beyond all doubt. Compact green hornblende appears to replace original diallage in the gabbro-like diorite which forms the barrier rock at Upper Quinnesec Falls (see Pl. X, fig. 1), where it even retains the orthopinacoidal parting. The same mineral likewise seems to replace original augite in many of the Horse Race diorites, whose structure is typically diabasic.

Fibrous green hornblende or uralite is too common and well known an alteration product of pyroxene to deserve especial description. It is universally distributed through all of the more basic rocks in the areas investigated.

A colorless chlorite may be seen originating from the almost colorless diallage of the Sturgeon Falls gabbro, as shown in Pl. VIII, fig. 2. From the varieties of pyroxene which are richer in iron, a deep green chlorite results which is often associated with epidote, as shown in Pl. XI, fig. 1.

Hornblende.—Without reference to the original or secondary origin of the hornblende itself, this mineral is found subject to several different alterations.

It passes from the compact to the fibrous form by fraying out at the ends, as shown in specimen No. 11175, from the Four-Foot Fall (see Fig. 19, p. 126). It also seems to give rise to biotite in many of the Horse Race diorites and in the amphibole granite, No. 11831, obtained at the camp northwest of Marquette. (See Pl. XVI. fig. 2.) Talc

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frequently is produced by hornblende alteration in the Horse Race diorites as described in Chap. III (p. 107). A colorless chlorite, closely resembling that produced from the Sturgeon Falls diallage, is derived from the pale hornblende (itself probably paramorphic) of No. 11098, from the ridge near Lower Quinnesec Falls. This is produced in spots over the hornblende and is visible only by its isotropic behavior in polarized light, as shown in Fig. 9 (p. 79). The viridite (chlorite) epidote aggregate originates from hornblende just as it does from pyroxene. Finally serpentine is an exceptional result of hornblende alteration, as may be seen in specimens 11078 and 11191 from the Horse Race (p. 109).

Biotite shows the usual alterations and is principally the result of weathering rather than of metamorphic processes. Bleaching first takes place and then chloritization. Carbonates are sometimes separated in the form of interpolated lenses, while the titanium which entered into their composition separates out sometimes as anatase (Nos. 11050 and 11052 from Upper Quinnesec Falls) and sometimes as rutile.[1] (Nos. 11113, from near Iron Mountain in the Menominee valley, No. 11672 from Marquette and No. 11738 from the Brook Section.)

Olivine occurs only in a few of the Marquette diabases, where its alteration is the usual one to serpentine.

Ilmenite is the last of the important original constituents of the Menominee and Marquette massive rocks whose alterations can be clearly traced. This gives rise to a variety of new titanium minerals

Its commonest change is that to leucoxene, which is everywhere encountered, see Pl. IX, figs. 1 and 2.

Sphene or titanite, of which leucoxene is only a special form, sometimes originates from ilmenite, as is shown in Pl. XIII, fig. 1, and in Pl. XVI, fig. 2.

Anatase also, in association with leucoxene, is a secondary product of ilmenite alteration. This is shown in Fig. 25 (p. 131) of No. 11130, from Twin Falls, as well as in No. 11802, one of the stretched agglomerates on the Carp River. (See Chap. V, p. 177.)

[1] On the frequency of these changes see Whitman Cross: "Petrography of the Leadville Rocks" in Mon. U. S. Geol. Survey, vol. 12, 1887.

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PLATES.

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PLATE VIII.

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PLATE VIII.

FIG. 1.—*Saussurite gabbro (first stage).*

From point *h*, Pl. III, at Sturgeon Falls, Menominee River, Michigan. Specimen No. 11167*a*. Ordinary light. (See p. 68.)

The triclinic feldspar, which shows occasional idiomorphic forms indicating that it is in part, at least, older than the pyroxene, here appears almost completely altered to an opaque, gray saussurite. A high magnifying power resolves this into an aggregate of minute zoisite needles, calcite and albite. These are somewhat unevenly distributed which produces the blotched appearance of the saussurite.

The diallage, which is of a pale green color in the hand-specimen, is almost colorless when seen under the microscope. Its well marked orthopinacoidal parting is seen on the right of the figure. This diallage is surrounded by a border of compact hornblende, which is either brown, pale green or colorless. It frequently becomes fibrous on its exterior edge, as is shown in Fig. 7, on p. 70. Small patches of compact brown hornblende are also abundantly scattered over the entire surface of the diallage in a manner that would seem to indicate that it had originated from the latter by paramorphism. There is some pale green chlorite visible in the upper part of the drawing and on the right is a bit of ilmenite and leucoxene.

FIG. 2.—*Saussurite gabbro (second stage).*

From point *f*, Pl. III, at Sturgeon Falls, Menominee River, Michigan. Specimen No. 11154. Represented between crossed nicol prisms. (See p. 72.)

A large individual of the pale diallage is here seen in an advanced stage of alteration to a colorless chlorite. Because of the almost isotropic character of this mineral, it is necessary to show its appearance in polarized light. Imbedded in the chlorite are remnants of the still brightly polarizing diallage, and around it is the border of hornblende, which here shows pale yellow interference colors.

The feldspar is less completely saussuritized than in the last figure. Its characteristic twinning lamellæ are still visible in many instances, particularly at the center of the crystals.

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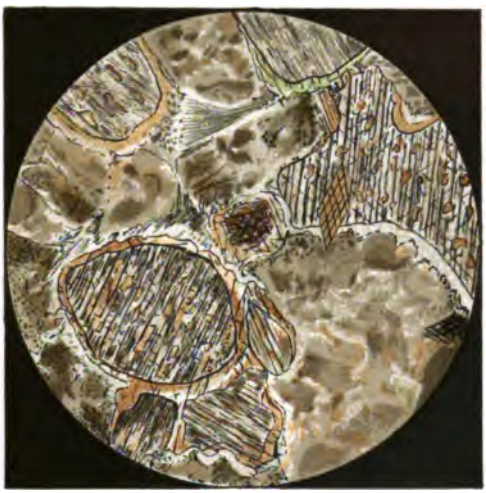

FIG. 1 (X30)

FIG. 2 (X30)

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PLATE IX.

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PLATE IX.

FIG. 1.—*Altered diabase or diorite.*

From the so-called "Gabbro Ridge," below Lower Quinnesec Falls, Menominee River, Michigan. Specimen No. 11028. Ordinary light. (See p. 81.)

The original structure of this rock has been completely changed, in spite of its still massive character. It is now composed of pale green, fibrous hornblende, saussurite, quartz, calcite, chlorite, ilmenite, and leucoxene. Most of these constituents are of secondary origin, and in the process of their formation the form of the primitive minerals has been so completely obliterated that it is now impossible to say whether the mother-rock was a diabase or a diorite.

FIG. 2.—*Schistose band in the last figured rock, showing the effect of dynamic metamorphism (stretching) upon it.*

Locality same as that of last figure. Specimen No. 11031. Ordinary light. (See p. 82.)

The feldspar in this rock is chemically less altered than in the last, but it has been subjected to a much more intense mechanical action. It is fractured, and the fragments are widely separated, although those pieces which once belonged to the same crystal may still often be identified. The interstices are filled with scales of a green chlorite, arranged parallel to one another, so as to produce a schistose structure. Even the little leucoxene zones around the ilmenite grains have been elongated in the same direction.

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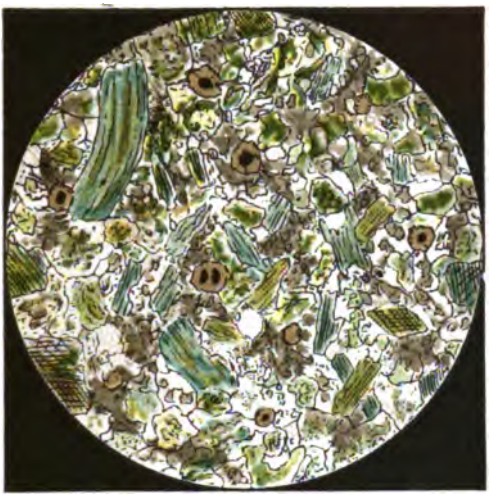

FIG 1 (X80)

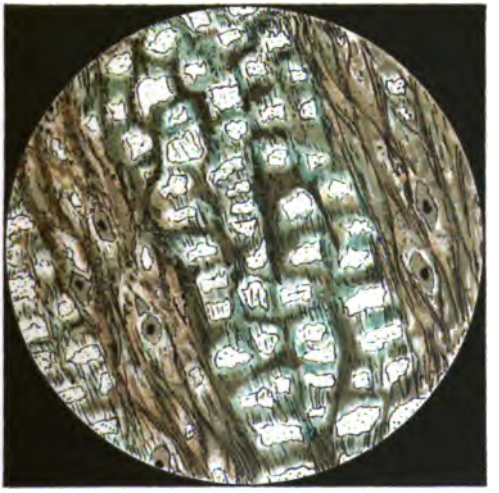

FIG. 2 (X80)

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PLATE X.

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PLATE X.

FIG. 1.—*Saussurite diorite.*

This rock forms the barrier at Upper Quinnesec Falls, Menominee River, Michigan. Specimen No. 11054. Ordinary light. (See p. 103.)

In spite of the close external resemblance of this rock to the Sturgeon Falls saussurite gabbro (Pl. VIII, fig. 1), it shows no trace of any pyroxenic constituent. Its only bisilicate is hornblende. This is sometimes compact (and then both brown and green in color), sometimes ragged and fibrous. The former variety is seen in the center and on the left of the figure, with its remarkably perfect orthopinacoidal parting, like that recently observed by Cathrein in a hornblende from Roda, in the Tyrol. This parting may be an indication that this hornblende has been derived from original diallage. A large individual of the more ragged and fibrous hornblende, filled with secondary quartz, is shown on the right of the figure.

The feldspar of this rock has undergone the usual alteration to opaque, gray saussurite, but in this are imbedded frequent grains of a fresh brown feldspar. Leucoxene rims around the ilmenite are abundant.

FIG. 2.—*Typical aphanitic greenstone of the Marquette region.*

From Baldwin's Kilns, northeast of Negaunee, Michigan. Specimen No. 11747. Ordinary light. (See p. 172.)

This is a fair representative of the commonest rock type in the southern Marquette and Negaunee greenstone areas. Its grain must always have been very fine and compact. Long, slender feldspar crystals may still be seen, sometimes with an imperfectly developed form, such as is common in the semi-crystalline rocks (porphyrites). The groundmass is composed of a fine grained aggregate of fibrous hornblende, chlorite, quartz, calcite, and ilmenite leucoxene. These minerals are all secondary, and may easily have resulted from the alteration of a cryptocrystalline, or even a partially vitreous base.

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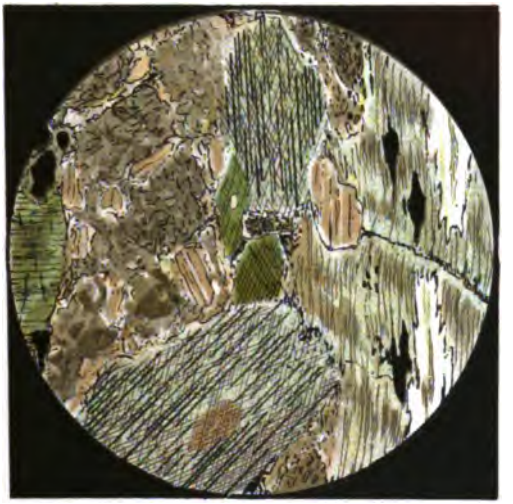

FIG. 1 (X30)

FIG 2 (X110)

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PLATE XI.

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PLATE XI.

FIG. 1.—*Chlorite-epidote aggregate in an altered diabase.*

From below Upper Quinnesec Falls, Menominee River, Michigan. Specimen No. 11049. Ordinary light. (See p. 97.)

This is a very common alteration product in rocks of the diabase type, especially in those rich in iron. In a confused mass of deep green and somewhat pleochroic chlorite scales lie embedded extremely sharp crystals of a yellowish or colorless epidote. These latter are what the earlier students of these rocks mistook for secondary augite. In the lower part of the figure are seen ilmenite grains surrounded by rims of leucoxene and a portion of a large secondary hornblende crystal.

FIG. 2.—*Stretched greenstone.*

From above Lower Quinnesec Falls, Menominee River, Michigan. Specimen No. 11102. Ordinary light. (See p. 94.)

The effects of tension upon a solid rock mass are rarely seen more distinctly than in this specimen. Not only the feldspar, but also a large grain of ilmenite has here been forcibly torn asunder, and the fragments have been separated a considerable distance, always in one direction. The peculiar green chlorite so characteristic of all stretched basic rocks (cf. Pl. IX, fig. 2) fills the interstices between the mineral fragments. It must have crystallized after the breaking of the solid rock constituents and its scales, which are all arranged parallel to the direction in which the strain was exerted, produce a decidedly schistose structure in the rock. The fresh state of the feldspar in a rock which has been subjected to such intense mechanical action as this one is very noticeable.

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FIG. 1 (X180)

FIG. 2 (X30)

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PLATE XII.

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PLATE XII.

FIG. 1.—*Coarsely crystalline diorite.*

From near Baldwin's Kilns, northeast of Negaunèe, Michigan. Specimen No. 11749. Ordinary light. (See p. 173.)

This one of the coarse grained dike rocks which penetrate the aphanitic greenstones of the Negaunee area. The hornblende is idiomorphic, and, as there are no certain traces of pyroxene, the rock is designated a "diorite." The feldspar is quite filled with secondary actinolite or epidote needles. The hornblende is often altered internally to chlorite or fibrous amphibole, while its exterior still remains compact and shows a curious concentration of the green coloring matter. There is also observable around the edge of the hornblende crystals a separation into fibers, as described by Becke.

FIG. 2.—*Epidiorite.*

From the Horse Race above Upper Quinnesec Falls, Menominee River, Michigan. Specimen No. 11186. Ordinary light. (See p. 107.)

This is one of the coarse grained dioritic rocks so abundant along the Horse Race Rapid. The pale green hornblende is entirely allotriomorphic and fills the spaces between the idiomorphic feldspar crystals exactly as augite does in diabase. Still there is no certain trace of pyroxene now present. The hornblende shows a deeper color around its edge and a breaking up into fibers, which are arranged in irregular bundles and appear to wander off into the surrounding feldspar.

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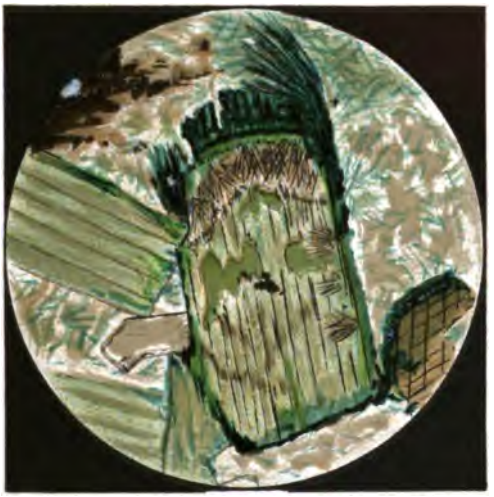

FIG. 1 (X110)

FIG. 2 (X110)

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PLATE XIII.

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PLATE XIII.

FIG. 1.—*Sphene crystals around ilmenite.*

In a dioritic rock from the Horse Race Rapid, above Upper Quinnesec Falls, Menominee River, Michigan. Specimen No. 11189. Ordinary light. (See p. 109.)

These sphene crystals, although their minerological character is undoubted, are not so clear or so sharply defined as usual. They are gray and cloudy, resembling leucoxene in appearance; and, like this substance which is known to be identical with sphene in its composition, these crystals surround grains of ilmenite, as though they had originated from its alteration. If this be the case, we have here an interesting example of leucoxene assuming its characteristic titanite form.

FIG. 2.—***Rutile originating from the alteration of ilmenite.***

In a greenstone from below the Upper Quinnesec Falls, Menominee River, Michigan. Specimen No. 11070. Ordinary light. (See p. 99.)

The rock, which was probable once a diabase, now consists principally of green chlorite and reddish feldspar substance. The opaque iron oxide now present is magnetite. This occupies irregular areas and is intimately associated with a network of yellow rutile needles in a manner which renders probable the origin of both of these minerals from an original ilmenite.

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FIG. 1 (X80)

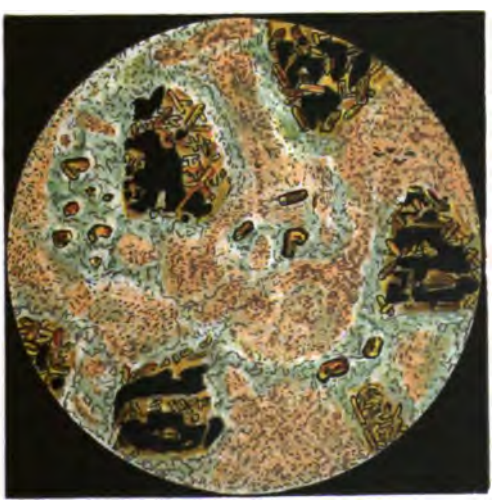

FIG 2 (X110)

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PLATE XIV.

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PLATE XIV.

FIG. 1.—*Sericite porphyry.*

From just below the Upper Quinnesec Falls, Menominee River, Wisconsin. Specimen No. 11050. Nicols crossed. (See p.121.)

This rock, which was once an eruptive quartz porphyry, shows in an admirable manner the effect of stretching. The porphyritic quartz crystals are somewhat elongated and testify to the tension to which they have been subjected by an undulatory extinction. The porphyritic feldspar crystals are fractured and pulled apart always in the same direction, without reference to the position which they themselves occupied in the rock. The fissures are cemented by a new crystallization of sericite. The microgranitic groundmass has been rendered schistose by stretching and by the abundant production of sericite, whose scales have a parallel arrangement.

FIG. 2.—*Stretched and brecciated greenstone.*

From near the Carp River, north of Teal Lake, Michigan. Specimen 11803. Nicols crossed. (See p.177.)

Some of the interstitial material, occurring between the massive cores of the spheroidally parted (brecciated) greenstones, contains distinct crystals of white feldspar. Between the eastern end of Teal Lake and the Carp River some of these massive cores are themselves much elongated by stretching. (See Fig. 27, p.177.) A section of the insterstitial material from this locality was selected for illustration because of the distinctness with which this stretching is apparent in the feldspar crystals. They are always broken and pulled apart in the same direction, while the smaller components of the rock show a corresponding elongation. The continuity of the original rock-structure in the interstitial portion of this exposure indicates that the spheroidal parting is in this case a result of cooling, rather than of mechanical brecciation in situ. (See p. 167.)

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FIG. 1 (X30)

FIG. 2 (X30)

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PLATE XV.

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PLATE XV.

FIG. 1.—*Structure of one of the "Augen" in an "Augengneiss," or stretched granite porphyry.*

From a schistose dike in the greenstones of the Horse Race Rapid above Upper Quinnesec Falls, Menominee River, Michigan. Specimen No. 11184. Ordinary light. (See p. 118.)

The center of the "Auge," or eye, is seen to consist of a portion of an old, brown colored porphyritic feldspar crystal. This is granulated on either side, and pulled out into a lens, whose longest axis agrees with the direction of the foliation. The granulation is composed of a new crystallization of the feldspar substance, which is clear, and although granitic in structure, it has a much coarser grain than the rest of the rock. This formation of an "Auge" out of a porphyritic feldspar crystal agrees with the observations of J. Lehmann, Chelius, and others.

FIG. 2.—*Stretched quartz porphyry.*

From a conformable dike in the schistose greenstones of the Brook Section, west of Marquette, Mich. Specimen No. 11707. Nicols crossed. (See p. 150.)

This rock is particularly noticeable on account of the wonderful manner in which it shows the effects of a stretching action upon quartz. The original crystals are elongated into lenticular and pear shaped forms, or even into long, narrow bands. The first effect of the tension is to disturb the optical homogeneity and produce an undulatory extinction. If, however, the strain is great enough to overcome the force of cohesion, a mosaic of interlocking and differently orientated grains is the result. Similar phenomena have been observed and illustrated by J. Lehmann in Saxony. The porphyritic feldspar crystals in this rock are not broken, nor do they show the evidence of great pressure. Their form is generally intact, but it is worthy of remark that their center is always occupied by an irregular area of microcline.

The groundmass is finely microgranitic, containing sinuous bands of micaceous minerals, which bend around the porphyritic constituents, while they follow the general direction of the foliation.

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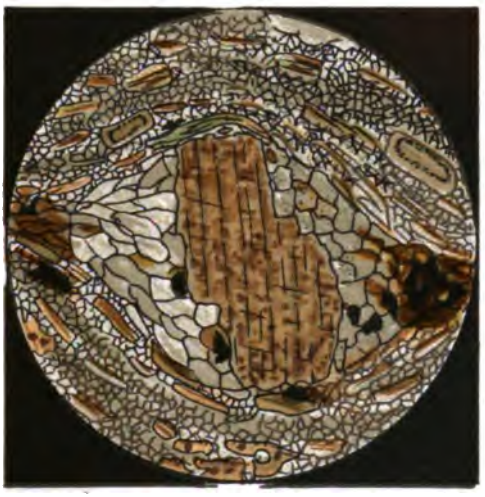

FIG. 1 (X30)

FIG. 2 (X30)

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PLATE XVI.

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PLATE XVI.

FIG. 1.—*Greenstone schist (tuff) of the northern Marquette area.*

Lighthouse Point, Marquette, Mich. Specimen No. 11619. Ordinary light. (See p. 155.)

A characteristic, although by no means universal structure, in the banded green schists which compose so large a portion of the region around Marquette, consists in the tufted form of the hornblende crystals. These, although quite compact at their centers, are fibrous at the ends and expand so as to resemble sheaves tied in the middle. The fibers are so fine and the radial arrangement at the ends of the bundles is so perfect that the arm of a black cross is seen to sweep across the field when the thin section is viewed between crossed nicol-prisms. Hornblende with a structure like this has been observed by Renard and others as a new crystallization in altered sediments, a fact which lends additional support to the hypothesis that these green schists are tuff deposits.

FIG. 2.—*Amphibole granite (?) forming a dike in aphanitic greenstones.*

Northeast of Negaunee, Mich. Specimen No. 11831. Ordinary light in part; polarized light in part. (See p. 181.)

This rock presents many points of interest, both in its structure and alteration products. The feldspar is in two distinct generations, of which the older variety is entirely idiomorphic, with a zone of clear substance surrounding a gray and more altered interior.

The hornblende exhibits the unusual alteration to biotite, which is sometimes brown, sometimes green. This mineral in rare instances has crystallized in sharp hexagonal plates which show pressure lines of cleavage ("Drucklinien").

The groundmass of this rock is an aggregate of quartz and the younger generation of feldspar. These sometimes form a microgranitic mosaic and sometimes micropegmatitic growths, which are represented in the figure as they appear in polarized light. Apatite is abundant, and also ilmenite or magnetite surrounded by chlorite, and in some cases by sphene, as though this had resulted from the alteration of the ilmenite, as shown in Pl. XIII, fig. 1.

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FIG. 1 (X30)

FIG. 2 (X30)

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22. On New Cretaceous Fossils from California, by Charles A. White. 1885. 8°. 25 pp. 5 pl. Price 5 cents.

23. Observations on the Junction between the Eastern Sandstone and the Keweenaw Series on Keweenaw Point, Lake Superior, by R. D. Irving and T. C. Chamberlin. 1885. 8°. 124 pp. 17 pl. Price 15 cents.

24. List of Marine Mollusca, comprising the Quaternary Fossils and recent forms from American Localities between Cape Hatteras and Cape Roque, including the Bermudas, by William Healey Dall. 1885. 8°. 336 pp. Price 25 cents.

25. The Present Technical Condition of the Steel Industry of the United States, by Phineas Barnes. 1885. 8°. 85 pp. Price 10 cents.

26. Copper Smelting, by Henry M. Howe. 1885. 8°. 107 pp. Price 10 cents.

27. Report of work done in the Division of Chemistry and Physics, mainly during the fiscal year 1884–'85. 1886. 8°. 80 pp. Price 10 cents.

28. The Gabbros and Associated Hornblende Rocks occurring in the Neighborhood of Baltimore, Md., by George Huntington Williams. 1886. 8°. 78 pp. 4 pl. Price 10 cents.

29. On the Fresh-water Invertebrates of the North American Jurassic, by Charles A. White. 1886. 8°. 41 pp. 4 pl. Price 5 cents.

30. Second Contribution to the Studies on the Cambrian Faunas of North America, by Charles Doolittle Walcott. 1886. 8°. 369 pp. 33 pl. Price 25 cents.

31. Systematic Review of our Present Knowledge of Fossil Insects, including Myriapods and Arachnids, by Samuel Hubbard Scudder. 1886. 8°. 128 pp. Price 15 cents.

32. Lists and Analyses of the Mineral Springs of the United States; a Preliminary Study, by Albert C. Peale. 1886. 8°. 235 pp. Price 20 cents.

33. Notes on the Geology of Northern California, by J. S. Diller. 1886. 8°. 23 pp. Price 5 cents.

34. On the relation of the Laramie Molluscan Fauna to that of the succeeding Fresh-water Eocene and other groups, by Charles A. White. 1886. 8°. 54 pp. 5 pl. Price 10 cents.

35. Physical Properties of the Iron-Carburets, by Carl Barus and Vincent Strouhal. 1886. 8°. 62 pp. Price 10 cents.

36. Subsidence of Fine Solid Particles in Liquids, by Carl Barus. 1886. 8°. 58 pp. Price 10 cents.

37. Types of the Laramie Flora, by Lester F. Ward. 1887. 8°. 354 pp. 57 pl. Price 25 cents.

38. Peridotite of Elliott County, Kentucky, by J. S. Diller. 1887. 8°. 31 pp. 1 pl. Price 5 cents.

39. The Upper Beaches and Deltas of the Glacial Lake Agassiz, by Warren Upham. 1887. 8°. 84 pp. 1 pl. Price 10 cents.

40. Changes in River Courses in Washington Territory due to Glaciation, by Bailey Willis. 1887. 8°. 10 pp. 4 pl. Price 5 cents.

41. On the Fossil Faunas of the Upper Devonian—the Genesee Section, New York, by Henry S. Williams. 1887. 8°. 121 pp. 4 pl. Price 15 cents.

42. Report of work done in the Division of Chemistry and Physics, mainly during the fiscal year 1885–'86. F. W. Clarke, chief chemist. 1887. 8°. 152 pp. 1 pl. Price 15 cents.

43. Tertiary and Cretaceous Strata of the Tuscaloosa, Tombigbee, and Alabama Rivers, by Eugene A. Smith and Lawrence C. Johnson. 1887. 8°. 189 pp. 21 pl. Price 15 cents.

44. Bibliography of North American Geology for 1886, by Nelson H. Darton. 1887. 8°. 35 pp. Price 5 cents.

45. The Present Condition of Knowledge of the Geology of Texas, by Robert T. Hill. 1887. 8°. 94 pp. Price 10 cents.

46. Nature and Origin of Deposits of Phosphate of Lime, by R. A. F. Penrose, jr., with an Introduction by N. S. Shaler. 1888. 8°. 143 pp. Price 15 cents.

47. Analyses of Waters of the Yellowstone National Park, with an Account of the Methods of Analsyis employed, by Frank Austin Gooch and James Edward Whitfield. 1888. 8°. 84 pp. Price 10 cents.

48. On the Form and Position of the Sea Level, by Robert Simpson Woodward. 1888. 8°. 88 pp. Price 10 cents.

49. Latitudes and Longitudes of Certain Points in Missouri, Kansas, and New Mexico, by Robert Simpson Woodward. 1889. 8°. 133 pp. Price 15 cents.

50. Formulas and Tables to facilitate the Construction and Use of Maps, by Robert Simpson Woodward. 1889. 8°. 124 pp. Price 15 cents.

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51. On Invertebrate Fossils from the Pacific Coast, by Charles Abiathar White. 1889. 8°. 102 pp. 14 pl. Price 15 cents.

52. Subaërial Decay of Rocks and Origin of the Red Color of Certain Formations, by Israel Cook Russell. 1889. 8°. 65 pp. 5 pl. Price 10 cents.

53. The Geology of Nantucket, by Nathaniel Southgate Shaler. 1889. 8°. 55 pp. 10 pl. Price 10 cents.

54. On the Thermo-Electric Measurement of High Temperatures, by Carl Barus. 1889. 8°. 313 pp. incl. 1 pl. 11 pl. Price 25 cents.

55. Report of work done in the Division of Chemistry and Physics, mainly during the fiscal year 1886-'87. Frank Wigglesworth Clarke, chief chemist. 1889. 8°. 96 pp. Price 10 cents.

56. Fossil Wood and Lignite of the Potomac Formation, by Frank Hall Knowlton. 1889. 8°. 72 pp. 7 pl. Price 10 cents.

57. A Geological Reconnaissance in Southwestern Kansas, by Robert Hay. 1890. 8°. 49 pp. 2 pl. Price 5 cents.

58. The Glacial Boundary in Western Pennsylvania, Ohio, Kentucky, Indiana, and Illinois, by George Frederick Wright, with an introduction by Thomas Chrowder Chamberlin. 1890. 8°. 112 pp. incl. 1 pl. 8 pl. Price 15 cents.

59. The Gabbros and Associated Rocks in Delaware, by Frederick D. Chester. 1890. 8°. 45 pp. 1 pl. Price 10 cents.

60. Report of work done in the Division of Chemistry and Physics, mainly during the fiscal year 1887-'88. F. W. Clarke, chief chemist. 1890. 8°. 174 pp. Price 15 cents.

61. Contributions to the Mineralogy of the Pacific Coast, by William Harlow Melville and Waldemar Lindgren. 1890. 8°. 40 pp. 3 pl. Price 5 cents.

63. A Bibliography of Paleozoic Crustacea from 1698 to 1889, including a list of North American species and a systematic arrangement of genera, by Anthony W. Vogdes. 1890. 8°. 177 pp. Price 15 cents.

64. A Report of work done in the Division of Chemistry and Physics, mainly during the fiscal year 1888-'89. F. W. Clarke, chief chemist. 1890. 8°. 60 pp. Price 10 cents.

66. On a Group of Volcanic Rocks from the Tewan Mountains, New Mexico, and on the occurrence of Primary Quartz in certain Basalts, by Joseph Paxson Iddings. 1890. 8°. 34 pp. Price 5 cents.

In press:

62. The Greenstone Schist Areas of the Menominee and Marquette Regions of Michigan, by George H. Williams; with an Introduction by R. D. Irving.

65. Comparative Stratigraphy of the Bituminous Coal Rocks of the Northern Half of the Appalachian Field, by I. C. White.

67. On the relations of the Traps of the Newark System in the New Jersey Region, by Nelson H. Darton.

In preparation:

— Natural Gas Districts in Indiana, by Arthur John Phinney.
— A Classed and Annotated Bibliography of Fossil Insects, by Samuel Hubbard Scudder.
— The Viscosity of Solids, by Carl Barus.
— Mesozoic Fossils in the Permian of Texas, by C. A. White.
— A Late Volcanic Eruption in Northern California and its Peculiar Lava, by J. S. Diller.
— Altitudes between Lake Superior and the Rocky Mountains, by Warren Upham.

STATISTICAL PAPERS.

Mineral Resources of the United States, 1882, by Albert Williams, jr. 1883. 8°. xvii, 813 pp. Price 50 cents.

Mineral Resources of the United States, 1883 and 1884, by Albert Williams, jr. 1885. 8°. xiv, 1016 pp. Price 60 cents.

Mineral Resources of the United States, 1885. Division of Mining Statistics and Technology. 1886. 8°. vii, 576 pp. Price 40 cents.

Mineral Resources of the United States, 1886, by David T. Day. 1887. 8°. viii, 813 pp. Price 50 cents.

Mineral Resources of the United States, 1887, by David T. Day. 1888. 8°. vii, 832 pp. Price 50 cents.

Mineral Resources of the United States, 1888, by David T. Day. 1890. 8°. vii, 653 pp. Price 50 cents.

The money received from the sale of these publications is deposited in the Treasury, and the Secretary of that Department declines to receive bank checks, drafts, or postage stamps; all remittances, therefore, must be by POSTAL NOTE or MONEY ORDER, made payable to the Librarian of the U. S. Geological Survey, or in CURRENCY, for the exact amount. Correspondence relating to the publications of the Survey should be addressed

TO THE DIRECTOR OF THE
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

WASHINGTON, D. C., *August*, 1890.

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DEPARTMENT OF THE INTERIOR

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No. 63

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GOVERNMENT PRINTING OFFICE
1890

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UNITED STATES GEOLOGICAL SURVEY
J. W. POWELL, DIRECTOR

A BIBLIOGRAPHY

OF

PALEOZOIC CRUSTACEA

FROM

1698 to 1889

INCLUDING A LIST OF NORTH AMERICAN SPECIES AND A SYSTEMATIC ARRANGEMENT OF GENERA

BY

ANTHONY W. VOGDES

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF PALEOZOIC INVERTEBRATE PALEONTOLOGY,
Washington, D. C., May 1, 1890.

SIR: I have the honor to transmit herewith, for publication, a bibliography of Paleozoic Crustacea, prepared by Lieutenant A. W. Vogdes, U. S. A.

The bibliography bears internal evidence of long continued and extended research and its publication will supply a work of reference that has long been needed by the student of invertebrate Paleozoic fossils.

I remain, very respectfully,

CHAS. D. WALCOTT,
Paleontologist.

Hon. J. W. POWELL,
Director U. S. Geological Survey.

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INTRODUCTION.

The sole object of this bulletin is to give a general view of the literature on the Paleozoic Crustacea and to aid students and paleontologists in their researches. It is the result of more or less constant work during the past ten years.

In its compilation I have examined almost every reference before recording it; those not so examined are indicated by a star (*) following the title.

For convenience, the subject-matter has been arranged as follows:

Part I. List of authors, including a brief index of the genera described in each work.

Part II. A catalogue of the North American Paleozoic trilobites.

Part III. The non-trilobitic Paleozoic Crustacea, with a list of the species.

I am well aware that the value of a work of this kind depends upon the care and labor given to its compilation. Every possible means of obtaining accurate information from a miscellaneous class of literature in many languages has been used, and it is hoped that there are but few errors and omissions.

I would thank those into whose hands this bulletin may fall for any information that would add to its value as a working hand-book.

A. W. VOGDES.

FORT HAMILTON, NEW YORK HARBOR, *April* 30, 1889.

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PART I.

LIST OF AUTHORS.

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A BIBLIOGRAPHY OF PALEOZOIC CRUSTACEA FROM 1698 TO 1889,

INCLUDING

A LIST OF NORTH AMERICAN SPECIES AND A SYSTEMATIC ARRANGEMENT OF GENERA.

By Anthony W. Vogdes.

PART I.

LIST OF AUTHORS.

A star (*) following a title indicates that the reference is recorded without opportunity for personal verification.

Agassiz (L.) Monographie des poissons fossiles du vieux grès rouge ou système dévonien (old Red Sandstone) des îles Britanniques et de Russie.

Text, Soleure; atlas, Neuchâtel, 1845, pp. xix–xx, note; and atlas, Tab. A.

Pterygotus n. g.

Alth (Alois von). Ueber die palæozoischen Gebilde Podoliens und deren Versteinerungen. Erste Abtheilung.

In Abhandl. k. k. geol. Reichsanst., vol. 7, pt. 1, Wien, 1874, 5 pl.

Proetus, *Cyphaspis*, *Dalmania*, *Calymene*, *Ceraurus*, *Sphærexochus*, *Encrinurus*, *Illænus*, *Eurypterus*, *Pterygotus*, *Stylonurus*, *Beyrichia*, *Leperditia*, *Primitia*, *Bairdia*.

Alton (Ed. de). See **Burmeister** and **Alton**.

Ami (Henry M.) Notes on *Triarthrus spinosus* Billings.

In Trans. Ottawa Field Nat. Club, No. 4, 1882–'83, p. 88, 1 pl.

Angelin (N. P.) Palæontologia Scandinavica. Pars I. Crustacea formationis transitionis. Lipsiæ, 1854, 4to.

The first part of this work, entitled "Palæontologia Scandinavica," containing pp. 1–24 and pl. 1–24, was published by the Royal Swedish Academy of Sciences in 1852. The second portion in 1854, including a preface, pp. 1–9 and pp. 21–92, pl. 25–42.

The genera are arranged in the following order: *Olenus*, *Paradoxides*, *Oryptonynus*, *Eryx*

Angelin (N. P.)—Continued.

n. g. (corrected by Angelin to *Elyx*, the generic term *Eryx* having been used by Stephen in 1832 for a genus of the Coleoptera), *Acontheus* n. g. (corrected by the author to that of *Aneucanthus*), *Agnostus*, *Phacops*, *Polytomurus*, *Remopleurides*, *Niobe* n. g., *Megalaspis* n. g., *Nileus*, *Ampyx*, *Proetus*, *Phæthonides* (Angelin uses this term for that of *Phæton* Barr.), *Forbesia*, *Gonioplcura*, *Celmus* n. g., *Anomocare* n. g., *Solenopleura* n. g., *Liostracus* n. g., *Calymene*, *Homalonotus*, *Pliomera* (*Amphion*), *Cheirurus*, *Cyrtometopus* n. g., *Acidaspis*, *Trapelocera*, *Sphærexochus*, *Acidaspis*, *Rhodope* n. g. (this term was used by Siebold in 1848 for a genus of the Gasteropoda), *Dysplanus*, *Bumastus*, *Illænus*, *Æglina*, *Olenus*, *Peltura*, *Parabolina*, *Acerocare* n. g., *Leptoplastus* n. g., *Eurycare* n. g. (this genus is referred by J. W. Salter, Mem. Geol. Survey United Kingdom, Brit. Organic Remains, decade xi, pl. 8, p. 3, to the genus *Sphærophthalmus* Ang.), *Sphærophthalmus* n. g., *Anopocare* n. g. (this genus is referred by J. G. O. Linnarsson, Geol. Förening. Stockholm Förhdl., vol. 5, 1880–'81, p. 136, to the genera *Peltura* and *Sphærophthalmus*; the specimen, according to Dr. Linnarsson, in the Royal Museum of Sweden, "marked by Angelin as the *abdomen till Stenom. pusillus*, contains several small heads of *Sphærophthalmus alatus*, and a small pygidium of *Peltura scarabæoides*;" Dr. Linnarsson refers to this specimen as Angelin's type for the genus *Anopocare* and also remarks "that Angelin intended to change the family name of *Sphærophthalmus alatus* and their nearest forms to that of *Stenometopus*, inasmuch as another specimen of *Sph. alatus* has, in Angelin's own hand-

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Angelin (N. P.)—Continued.

writing, the generic name of *Stenometopus*"), *Ptychopyge* n. g., *Asaphus*, *Bronteus*, *Holometopus* n. g., *Isocolus*, *Corynexochus* n. g., *Symphysurus*, *Euloma* n. g., *Pharostoma*, *Conocoryphe*, *Trinucleus*, *Sphærexocoryphe* n. g., *Deiphon*, *Staurocephalus*, *Lichas*, *Dolichometopus* n. g., *Platymetopus*, *Cyrtometopus*, *Ampyx*, *Raphiophorus*, *Lonchodomas*, *Harpes*, *Arraphus* n. g., *Harpides*, *Centropleura* n. g. (J. G. O. Linnarsson, Svenska Vetenak. Akad. Handl., vol. 8, 1869, No. 2, p. 71, cites Angelin's *Centropleura angusticauda* and *C. dicræura* under Dr. Owen's genus *Dikelocephalus*), *Cybele*, *Telephus*, *Ogygia*, *Ogygiocaris* n. g.

—— Palæontologia Scandinavica. Pars I. Crustacea formationis transitionis fasciculi 1 et 2 cum tabulis 48. Holmiæ, 1878 (3d ed.).

This work contains plates 1, 1a, 2, 3, 20, 22, with an appendix, pp. 93–96. Emended and revised by Prof. Gustaf Lindström.

The appendix contains descriptions and figures of the following species: *Paradoxides tessini*, *P. tessini* var. *wahlenbergii*, *P. tessini* var. *æslandicus*, *P. affinis*, *P. tuberculatus*, *P. forchhammeri*, *P. tumidus*, *Centropleura loveni*, *C. steenstrupi*, *Ogygiocaris dilatata*, *O. dilatata* var. *sarsi*, *O. dilatata* var. *strömi*, in addition to the genera and species described in the second edition.

Anthony (J. G.) New Trilobites.

In Am. Jour. Sci., 1st series, vol. 34, 1838, p. 379.

Ceratocephala ceralepta, figs. 1 and 2.

—— Description of a new fossil (*Calymene bucklandii*).

In Am. Jour. Sci., 1st series, vol. 36, 1839, p. 106.

In this article a specimen of *Ceraurus pleurexanthemus* Green was figured and described under the name of *Calymene bucklandii* as a new species.

Audouin (J. V.) Recherches sur les rapports naturels qui existent entre les Trilobites et les animaux articulés.

In Annales Gén. Sc. Phys. Nat., Bruxelles, vol. 8, 1821, pl. 18, p. 233; also Isis (oder Encyc. Zeitung), Oken, vol. 1, 1822, p. 87.

Calymene blumenbachii.

Baily (W. H.) On two new species of Crustacea (*Belinurus* König) from the Coal Measures in Queen's County, Ireland; and some remarks on forms allied to them.

In Rept. 28th Meeting Brit. Assoc. Adv. Sci., 1858, p. 76.

—— On the annuloid Crustacea of the Coal Measures. (*)

In Jour. Geol. Soc. Dublin, vol. 8, 1858, p. 89.

In this paper a description of a fossil Crustacean from the Bilboa Colliery, Queen's County, was given, with a few remarks on the allied species from Coal Brook Dale, which had been included with it in the genus *Limulus*, and it was proposed to remove all these Coal-Measure Crustacea from that genus and group them into a new one, under the name of *Steropis*.

—— Remarks on some Coal-Measure Crustacea belonging to the genus *Belinurus* König, with descriptions of two new species from Queen's County, Ireland. Pl. 5.

In Annals Nat. Hist., 3d series, vol. 2, 1863, p. 105. Translated by Milne-Edwards, Annales Gén. Sc. Phys. Nat., Bruxelles, 1863.

The author herein describes *Belinurus reginæ*, *B. arcuatus*, *B. bellulus*, *B. rotundus*?

Charles König in his work (Icones Fossilium Sectiles, London, 1825) simply mentions the name of *Belinurus bellulus* in his explanation of pl. 18, fig. 230.

—— Figures of characteristic British fossils, with descriptive remarks.

Pt. 1, pls. 1–10, Cambrian and Lower Silurian, London, 1867; pt. 2, pls. 11–20, 1869; pt. 3, pls. 21–30, 1871.

Paradoxides, *Dikelocephalus*?, *Olenus*, *Palæopyge*, *Conocoryphe*, *Angelina*, *Prostus*, *Phacops*, *Calymene*, *Homalonotus*, *Lichas*, *Trinucleus*, *Ampyx*, *Asaphus*, *Ogygia*, *Niobe*, *Proetocephalus*, *Ægline*, *Cheirurus*, *Sphærexochus*, *Encrinurus*, *Illænus*, *Agnostus*, *Eurypterus*, *Pterygotus*, *Ceratiocaris*, *Beyrichia*, *Cythere*, *Primitia*, *Hymenocaris*.

—— On Trilobites and other fossils from Lower or Cambro-Silurian strata in the county of Clare. (*)

In Jour. Royal Geol. Soc. Ireland, vol. 17, pt. 1, 1886, p. 29.

Banks (R. W.) On the tilestones or Downton sandstones, in the neighborhood of Kington, and their contents.

In Quart. Jour. Geol. Soc. London, vol. 12, 1856, p. 93, plate.

Pterygotus, *Pteraspis*, *Eurypterus*, *Himantopterus*.

Barrande (Joachim). Notice préliminaire sur le système silurien et les Trilobites de Bohême. Leipsic, 1846.

Étage C: *Paradoxides*, *Conocephalus*, *Ellipsocephalus*, *Arion* n. g., *Sao* n. g., *Baltus*, *Hydrocephalus* n. g., *Monadina* n. g.

Étage D: *Phacops*, *Calymene*, *Odontopleura*, *Asaphus*, *Cheirurus*, *Trinucleus*, *Caphyra* n. g., *Dions* n. g., *Illænus*, *Egle* n. g., *Battus*.

Étage E: *Phacops*, *Arethusa* n. g., *Sphærexochus*, *Asaphus*, *Cheirurus*, *Calymene*, *Staurocephalus* n. g., *Lichas*, *Harpes*, *Odontopleura*, *Cyphaspis*, *Bronteus*, *Phæton* n. g., *Prostus*.

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Barrande (Joachim)—Continued.

Étage F: *Phacops, Bronteus, Lichas, Proetus, Harpes, Cheirurus, Odontopleura, Cyphaspis.*

Étage G: *Phacops, Bronteus, Cheirurus, Cyphaspis, Odontopleura, Proetus.*

—— Nouveaux Trilobites. Supplément à la Notice préliminaire sur le système silurien et les Trilobites de Bohême. Prague, 1846.

Étage C: Schistes fossilifères.

Étage D: *Cheirurus, Phacops, Ampyx, Odontopleura, Illænus.*

Étage E: *Arethusa, Harpes.*

Étage F: *Proetus, Phæton, Bronteus, Odontopleura.*

Étage G: *Harpes, Cheirurus, Phacops.*

—— Ueber das Hypostoma und Epistoma, zwei analoge aber verschiedene Organe der Trilobiten.

In Neues Jahrbuch für Mineral., 1847, p. 385, pl. 8.

Phacops socialis, P. breviceps, Amphion, Illænus, Cheirurus, Asaphus, Lichas.

The generic term *Dions* is herein modified to that of *Dionide*, p. 391.

—— *Sao hirsuta* Barrande, ein Bruchstück aus dem "Système silurien du centre de la Bohême."

In Neues Jahrbuch für Mineral., 1849, p. 385, pl. 7.

Sao.

—— Note on Trilobites.

In Ber. Mittheil. Freunde Naturw., Wien, vol. 4, 1849, p. 353.

Noticed by J. W. Salter.

In Quart. Jour. Geol. Soc. London, vol. 5, 1849, pt. 2, p. 34.

—— *Deiphon forbesii*, neuer Trilobit aus Böhmen.

In Ber. Mittheil. Freunde Naturw., Wien, vol. 5, 1850, p. 6.

—— Versuch einer Klassification der Trilobiten.

In Neues Jahrbuch für Mineral., 1850, p. 769.

—— Système silurien du centre de la Bohême. 1re partie. Recherches paléontologiques. Prague et Paris, 1852.

Vol. 1. Text, Crustacés, Trilobites. With atlas of 51 pls.

This classical work contains a historical sketch of all the genera of Trilobites, and descriptions of the following genera:

Harpes, Remopleurides, Paradoxides, Hydrocephalus, Sao, Arionellus n. g., *Ellipsocephalus, Olenus, Peltura, Triarthrus, Conocephalites, Proetus, Phillipsia, Griffithides, Cyphaspis, Arethusina* (generic term changed from that of *Arethus* to *Arethusina*), *Harpides, Phacops, Dalmanites, Calymene, Homalonotus, Lichas, Trinucleus, Ampyx, Dionide* (generic term changed from *Dions* to *Dionide*), *Asaphus, Ogygia, Æglina* n. g., *Illænus, Nileus, Symphysurus, Acidaspis, Cheirurus, Placoparia, Sphærexochus, Staurocephalus, Deiphon, Dindymene, Zethus, Amphion, Encrinurus, Cromus* n. g., *Bronteus, Agnostus, Telephus* n. g.

—— On *Ceratiocaris bohemicus.*

In Neues Jahrbuch für Mineral., 1853, pt. 3, pp. 335–347.

On p. 335 of this article there is a review of Dr. D. D. Owen's Rept. Geol. Survey Wisconsin, Iowa, and Minnesota, Phila., 1852.

? Dicalocephalus, etc.

—— Note sur quelques nouveaux fossiles découverts aux environs de la ville de Rokitzan dans le bassin silurien du centre de la Bohême.

In Bull. Soc. Géol. France, 2d series, vol. 13, 1856, p. 532.

Calymene. Placoparia, Acidaspis, Agnostus, Amphyx, Harpes, Ogygia.

Mere mention of locality and period.

—— Wiedererscheinung der Gattung *Arethusina* Barrande.

In Neues Jahrbuch für Mineral., 1858, p. 257, 1 pl.

Arethusina sandbergeri Barr.

—— Documents anciens et nouveaux sur la faune primordiale et le Système Taconique en Amérique.

In Bull. Soc. Géol. France, 2d series, vol. 18, 1861, pp. 203–321, pls. 4, 5.

Paradoxides asaphoides Emmons, *P. thompsoni* Hall, *P. macrocephalus* Emmons, *P. vermontana* Hall, *Peltura* (*Olenus*) *holopyga* Hall, *Atops trilineatus* Emmons, *A. punctatus* Emmons, *Triarthrus becki* Green, *Microdiscus quadricostatus* Emmons.

—— I. Réapparition du genera *Arethusina* Barrande. II. Faune silurienne des environs de Hof, en Bavière. Prague et Paris, 1868.

Olenus, Conocephalites, Arethusina, Calymene, Bavarilla n. g., *Lichas, Asaphus, Cheirurus, Agnostus.*

—— Trilobites. I. Résumé général de nos études sur l'évolution des Trilobites. II. Distribution verticale des Trilobites dans le bassin silurien de la Bohême. III. Parallèle entre les Trilobites et Céphalopodes siluriens de la Bohême. IV. Épreuve des théories paléontologiques par la réalité. Prague et Paris, 1871.

—— Système silurien du centre de la Bohême. 1re partie. Recherches paléontologiques. Supplément au vol. 1.

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Barrande (Joachim)—Continued.

Trilobites. Crustacés divers et poissons. Prague et Paris, 1872, 32 pls.

Trilobites. *Harpes, Remopleurides, Paradoxides, Plutonia, Anopolenus, Dikelocephalus, Dolichometopus, Hydrocephalus, Olenus, Olenellus, Bohemilla, Conocephalites, Aneuacanthus, Angelina, Anomocare, Arionellus, Atops, Bathyurus, Chariocephalus, Corynexochus, Ellipsocephalus, Holocephalina, Ptychaspis, Sao, Triarthrus, Triarthrella, Proetus, Arethurina, Carinon* n. g., *Cyphaspis, Cyphoniscus, Harpides, Isocolus, Phillipsia, Phacops, Dalmanites, Calymene, Bavarilla, Homalonotus, Lichas, Trinucleus, Ampyx, Dionide, Endymionia, Microdiscus, Asaphus, Barrandia, Ogygia, Psilocephalus, Stygina, Æglina, Illænurus, Acidaspis, Cheirurus, Arsia, Crotalurus, Deiphon, Placoparia, Sphærexochus, Staurocephalus, Zethus, Dindymene, Amphion, Cromus, Encrinurus, Bronteus, Illænus, Nileus, Agnostus, Illænopsis, Pemphigaspis, Shumardia, Telephus* n. g., *Triopus.*

Phyllopoda. *Ceratiocaris, Aptychopsis* n. g., *Cryptocaris* n. g., *Pterocaris* n. g.

Ostracodes. *Aristozoe* n. g., *Beyrichia, Bolbozoe* n. g., *Callizoe* n. g., *Caryon* n. g., *Crescentilla* n. g., *Cythere, Cytheropsis* n. g., *Elpe* n. g., *Entomis, Hippa* n. g., *Isochilina, Leperditia, Nothozoe* n. g., *Orozoe* n. g., *Primitia, Zonozoe* n. g.

Eurypteridæ. *Pterygotus, Eurypterus.*

Cirrhipedia. *Anatifopsis* n. g., *Plumulites* n. g., *Bactropus* n. g., *Dryalus* n. g.

See Corda (A. J. C.) and Hawle (Ignaz).

—— and **Verneuil** (E. de). See **Verneuil** (E. de) and **Barrande** (Joachim).

Barrett (S. T.) The coralline or Niagara limestone of the Appalachian system as represented at Nearpass's Cliff, Montague, N. J.

In Am. Jour. Sci., 3d series, vol. 15, 1878, p. 370.

Proetus pachydermatus n. s.

—— Description of a new Trilobite, *Dalmanites dentata.*

In Am Jour. Sci., 3d series, vol. 11, 1876, p. 200, plate.

—— On *Dalmanites dentata.*

In Am. Jour. Sci., 3d series, vol. 12, 1876, p. 70.

Barris (W. H.) New fossils from the Corniferous formation at Davenport.

In Davenport Acad. Nat. Sci., vol. 2, 1879, p. 282, pls. 10 and 11.

Proetus davenportensis n. s., pl. 11, fig. 8.

Barrois (Charles). Note sur des fossiles de Cathervielle.

In Bull. Soc. Géol. France, 3d series, vol. 8, 1880, p. 266.

Phacops fecundus, Dalmanites hausmani, pl. 8.

Barrois (Charles)—Continued.

—— Recherches sur les terrains anciens des Asturies et de la Galice.

In Mém. Soc. Géol. Nord, Lille, vol. 2, 1882, 630 pp., 20 pls.

Paradoxides, Conocephalus, Arionellus.

—— Sur les faunes siluriennes de la Haute-Garonne. Pls. 6, 7.

In Annales Soc. Géol. Nord, Lille, vol. 10, 1883, p. 151.

Cyphaspis, Phacops, Dalmanites, Lichas.

—— Les appendices des Trilobites.

In Annales Soc. Géol. Nord, Lille, vol. 11, 1883–'84, p. 228.

—— Mémoire sur le calcaire à Polypiers de Cabrières (Hérault).

In Annales Soc. Géol. Nord, Lille, vol. 13, 1885–'86, p. 74, plate.

Phacops, Bronteus.

—— Sur la faune de Haut-de-Ver (Haute-Garonne).

In Annales Soc. Géol. Nord, Lille, vol. 13, 1885–'86, pls. 2, 3.

Harpes, Cyphaspis, Phacops, Dalmanites, Lichas, Bronteus.

—— Sur le calcaire dévonien de Chaudefonds (Maine-et-Loire).

In Annales Soc. Géol. Nord, Lille, vol. 13, 1885–'86, p. 170.

—— Aperçu de la constitution géologique de la rade de Brest.

In Bull. Soc. Géol. France, 3d series, vol. 14, 1886, p. 678, pls. 31–33.

Homalonotus le Hiri Barrois.

Baumer (J. W.) Naturgeschichte des Mineralreichs mit besonderer Anwendung auf Thüringen. 2 vols. Gotha, 1763–'64, 1767.

Bayle (E.) Explication de la carte géologique de la France. Vol. 4. Atlas. Paris, 1878.

Première partie. Fossiles principaux des terrains.

Pl. 1, *Megalaspis;* pl. 2, *Homalonotus;* pl. 3, *Calymene;* pl. 4, *Cheirurus, Illænus, Phacops, Cryphæus, Goldius, Prætus, Phillipsia;* pl. 5, *Acidaspis.*

Bean (W.) Entomostracans from the Coal Measures of Newcastle-upon-Tyne.

In Mag. Nat. Hist. (London), vol. 9, 1836, p. 376.

Beyrichia.

Beckmann (J.) Commentatio de reductione rerum fossilium ad genera naturalia protyporum.

In Novi Comm. Soc. Scient. Götting., vol. 2, 1778, p. 95.

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Beecher (C. E.) *Ceratiocaridæ* from the Upper Devonian Measures in Warren County.

In Second Geol. Survey Pennsylvania, vol. PPP, 1884, 2 pls.

Echinocaris, Elymocaris n. g., *Tropidocaris* n. g.

Author's edition issued separately, entitled: "*Ceratiocaridæ* from the Chemung and Waverly Groups at Warren, Pa.," with 2 pls., Harrisburg, 1884, 22 pp.

Belt (Thomas). On some new Trilobites from the Upper Cambrian rocks of North Wales.

In Geol. Mag., vol. 4, London, 1867, p. 294, pl. 12.

Agnostus pisiformis, A. nodosus, Olenus gibbosus.

—— On the Lingula flags or Festiniog group of the Dolgelly district.

In Geol. Mag., vol 5, London, 1868, p. 5, pl. 2.

Conocoryphe, Sphærophthalmus, Agnostus.

Bergeron (M.-T.) Étude paléontologique et stratigraphique des terrains anciens de la montagne Noire.

In Bull. Soc. Géol. France, 3d series, vol. 15, 1887, No. 5.

Harpes, Phacops, Cheirurus.

Beushausen (Louis). Beiträge zur Kenntniss des oberharzer Spiriferensandsteins und seiner Fauna. (*)

Inaugural-Dissertation. Göttingen, 1884, p. 34.

Beyrich (Ernst). Ueber einige böhmische Trilobiten. Berlin, 1845, 1 pl.

Lichas, Cheirurus n. g., *Sphærexochus* n. g., *Bronteus, Battus, Trochurus* n. g.

—— Untersuchungen über Trilobiten. Zweites Stück als Fortsetzung zu der Abhandlung "Ueber einige böhmische Trilobiten." Berlin, 1846, 3 pls.

Harpes, Harpides n. g., *Proetus, Calymene, Lichas, Trinucleus, Odontopleura, Cheirurus, Sphærexochus, Arges, Bronteus.*

Bigsby (J. J.) Description of a new species of Trilobite.

In Jour. Acad. Nat. Sc. Phila., vol. 4, pt. 2, 1825, p. 365, pl. 23.

Paradoxides boltoni (*Lichas boltoni*).

—— Thesaurus Siluricus. The flora and fauna of the Silurian period. London, 1868.

Billings (E.) Fossil foot prints.

In Canadian Naturalist, vol. 1, 1856, p. 35, wood-cuts.

Protichnites septem-notatus.

—— On some of the characteristic fossils of the Lower Silurian rocks of Canada.

Billings (E.)—Continued.

In Canadian Naturalist, vol. 1, 1856, p. 39, 11 wood-cuts.

The author figures *Isotelus gigas, Calymene senaria*, and the hypostoma of *Isotelus gigas.*

—— Fossils of the Upper Silurian rocks, Niagara and Clinton groups.

In Canadian Naturalist, vol. 1, 1856, p. 57, 1 pl.

Phacops limulurus Green.

—— Description of fossils occurring in the Silurian rocks of Canada.

In Canadian Naturalist, vol. 1, 1856, p. 312, 10 wood-cuts.

Homalonotus delphinocephalus Green.

—— Report for the year 1856 of E. Billings, esq., palæontologist, addressed to Sir Wm. E. Logan, etc.

In Geol. Survey Canada. Rept, Progress, 1853-'54-'55-'56, p. 247.

Triarthrus spinosus n. s., *Acidaspis horani* n. s., *Bronteus lunatus* n. s.

—— Fossils of the Calciferous sandrock, including those of a deposit of white limestone at Mingan, supposed to belong to the formation.

In Canadian Naturalist, vol. 4, 1859, p. 345, 12 wood cuts.

Bathyurus n. g., *Leperditia.*

—— Description of some new species of Trilobites from the Lower and Middle Silurian rocks of Canada.

In Canadian Naturalist, vol. 4, 1859, p. 367, 18 wood-cuts.

Triarthrus, Amphion, Illænus.

—— Fossils of the Chazy limestone, with descriptions of new species.

In Canadian Naturalist, vol. 4, 1859, p. 426, 38 wood-cuts.

Harpes, Bathyurus, Leperditia.

—— Description of some new species of fossils from the Lower and Middle Silurian rocks of Canada.

In Canadian Naturalist, vol. 5, 1860, p. 49, 16 wood-cuts.

Proetus, Phacops, Dalmanites, Cheirurus.

—— On some new species of fossils from the limestone near Point Levi, opposite Quebec.

In Canadian Naturalist, vol. 5, 1860. p. 301, 30 figs.

Dikelocephalus, Conocephalites, Arionellus, Bathyurus, Menocephalus, Asaphus, Cheirurus, Agnostus.

—— On some of the rocks and fossils occurring near Phillipsburg, Canada East.

In Canadian Naturalist, vol. 6, 1861, p. 310, 6 figs.

Bathyurus, Menocephalus, Amphion.

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Billings (E.)—Continued.

—— On some new or little-known species of Lower Silurian fossils from the Potsdam group (Primordial zone). Montreal, 1861, 24 pp.

This pamphlet, with the addition of a description of *Archæocyathus profundus*, the suppression of that of *A. minganensis*, and the notes on pages 10, 11, and 12, was reprinted in the "Palæozoic Fossils of Canada," vol. 1, 1865, pp. 1-24, also in part in the "Geol. Vermont," vol. 2, 1861, pp. 942-960.

Olenellus thompsoni Hall, *Olenellus vermontana* Hall, *Conocephalites miser* n. s., *C. adamsi* n. s., *C. teucer*, *C. vulcanus* n. s., *C. arenosus* n. s., *Bathyurus senectus* n. s., *B. parvulus* n. s., *Ampyx halli* n. s.

—— Description of a new species of *Harpes* from the Trenton limestone, Ottawa.

In Canadian Naturalist, vol. 8, 1863, p. 36, wood-cut.

Harpes dentoni n. s.

—— Geological Survey of Canada. Report of progress from its commencement to 1863. Illustrated by 498 wood-cuts in the text. Montreal, 1863. Atlas of maps and sections.

Harpes, *Paradoxides*, *Conocephalites*, *Triarthrus*, *Bathyurus*, *Proetus*, *Phacops*, *Dalmanites*, *Calymene*, *Lichas*, *Trinucleus*, *Asaphus*, *Illænus*, *Acidaspis*, *Cheirurus*, *Amphion*, *Encrinurus*, *Bronteus*, *Beyrichia*, *Leperditia*, *Isochilina*, *Eurypterus*, *Cytheropsis*.

—— Description of new species of *Phillipsia* from the Lower Carboniferous rocks of Nova Scotia.

In Canadian Naturalist, vol. 8, 1863, p. 209, 1 wood-cut.

Phillipsia howi.

—— Description of some new species of fossils, with remarks on others already known, from the Silurian and Devonian rocks of Maine.

In Proc. Portland Soc. Nat. Hist., vol. 1, 1869, p. 104, plate.

Dalmanites epicrates n. s., *Cheirurus tarquinius* n. s., *Proetus junius* n. s., *P. macrobius* n. s., *Bronteus pompilius* n. s., *Phacops trajanus* n. s., *Lichas*.

—— Palæozoic fossils. Vol. 1. Containing descriptions and figures of new or little known species of organic remains from the Silurian rocks. 1861-'65. 426 pp., 401 figures. Geol. Survey Canada.

The first portion of this work, consisting of 24 pages, was issued in November, 1861, and re-appears in this work, with the exception of the notes on pages 10, 11, and 12 of the original edition. The second part, consisting of pp. 25-56, was issued in January, 1862, and the third, pp. 57-168, in June, 1862; the fourth, pp. 169-344, in February, 1865.

Harpes, *Remopleurides*, *Olenus*, *Olenellus*, *Dolichometopus*, *Dikelocephalus*, *Telephus*, *Conocephalites*, *Arionellus*, *Bathyurus*, *Loganellus*, *Menocephalus*, *Triarthrus*, *Harpides*, *Lichas*, *Ampyx*, *Asaphus*, *Cheirurus*, *Sphærexochus*, *Amphion*, *Encrinurus*, *Illænus*, *Nileus*, *Agnostus*, *Beyrichia*, *Leperditia*, *Bathyurellus* n. g., *Shumardia* n. g., *Endymion* n. g. (this name was changed by the author to that of *Endymionia* on p. 281).

—— Catalogue of the Silurian fossils of the island of Anticosti, with descriptions of some new genera and species. 1866. 93 pp., 28 figs. Geol. Survey Canada.

Harpes, *Sphærocoryphe*, *Proetus*, *Dalmanites*, *Calymene*, *Lichas*, *Dionide*, *Asaphus*, *Cheirurus*, *Sphærexochus*, *Encrinurus*, *Bronteus*, *Illænus*, *Beyrichia*, *Leperditia*.

—— Note on some specimens of Lower Silurian Trilobites.

In Quart. Jour. Geol. Soc. London, vol. 26, 1870, p. 479, pls. 31, 32.

Asaphus platycephalus Stokes, with some of the legs preserved.

—— Palæozoic fossils. Vol. 2, pt. 1. 1874.

In Geol. Survey Canada, 144 pp., 35 figs. and 9 pls.

Paradoxides, *Anopolenus*, *Agraulos*, *Solenopleura*.

—— On some new or little known fossils from the Silurian and Devonian rocks of Canada.

In Canadian Naturalist, new series, vol. 7, 1874, p. 230.

Lichas superbus n. s.

Blumenbach (J. F.) Abbildungen naturhistorischer Gegenstände. Göttingen, 1810.

The author remarks on a species of *Calymene blumenbachii*, which he figures on pl. 50, that "according to all analogy it must have been without doubt the petrifaction of some species of insect without wings."

The specimen was from Dudley limestone and afterwards named by Alex. Brongniart *Calymene blumenbachii*.

Boeck (C.) Notitzer til Læren om Trilobiten. (*)

In Nyt Mag. Naturvid., vol. 1, Christiania, 1827, p. 11.

Trilobitern tesseni, *T. spinosus major*, *T. spinosus minor*, *T. gracilis*, *T. zippei*, *T. hausmanni*.

Noticed in Bull. Sci. Nat. (Férussac), vol. 14, 1828, p. 45.

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Boeck (C.)—Continued.

—— Uebersicht der bisher in Norwegen gefundenen Formen der Trilobiten-Familie. (*)

In Gæa Norwegica (Keilhau), Christiania, 1838, pt. 1, p. 138.

Trilobiten elliptifrons, T. elegans, T. hausmanni, T. semilunaris, T. punctatus, T. sphærieus, T. clavifrons, T. blumenbachii, T. fischeri, T. forficula, T. acicularis, T. lyra, T. grandis, T. angustifrons, T. dilatatus, T. expansus, T. acuminatus, T. limbatus, T. striatus, T. frontalis, T. crassicauda, T. centrotus, T. asellus, T. alatus, T. latus, T. granulatus, T. rostratus, T. mammillatus, T. scarabæoides.

—— Om Trilobiten.

In Skand. Naturf. Förhand., vol. 2, 1840, p. 289; Neues Jahrbuch für Mineral., 1841, p. 724.

Boll (Ernst). Beitrag zur Kenntniss der Trilobiten.

In Dunker and von Meyer's Palæontographica, vol. 1, Cassell, 1847, p. 126.

Ampyx, Battus.

—— Ueber die Arten der Gattung *Beyrichia* in norddeutschen Silurian-Geröllen.

In Zeitschr. deutsch. geol. Gesell., Berlin, vol. 8, 1856, p. 321, 4 figs.

A communication from Herr Boll to Herr Beyrich.

Beyrichia jonesi, B. spinulosa, B. hians.

—— Die Beyrichien der norddeutschen silurischen Gerölle.

In Archiv Vereins Freunde Naturg. Mecklenburg, 1862, p. 114, pl. 1.

Beyrichia.

Born (*Chev.* de). Lithophilacion Bornianum. Index fossillum quæ colleget in class. ac ordinis digessit. 2 vols. Pragæ, 1772. (*)

In Crustacea, vol. 2, p. 5.

Bornemann (J. G.) Palæontologisches aus dem cambrischen Gebiete von Camalgrande in Sardinien.

In Zeitschr. deutsch. geol. Gesell., Berlin, 1883, p. 270.

Olenellus zoppei, Conocoryphe sp.? (*Olenus armatus* Meng.), *Illænus meneghini.*

Bradley (Frank). Description of a new Trilobite from the Potsdam sandstone, with a note by E. Billings, of Montreal, Canada.

In Proc. Am. Assoc. Adv. Sci., 14th meeting, 1861, p. 161, 3 wood-cuts.

Conocephalites minutus.

See, also, Am. Jour. Sci., 2d series, vol. 30, 1860, p. 241; Canadian Naturalist, vol. 5, 1860, p. 420.

Brady (M. P.) See **Jones** (T. Rupert), **Kirkby** (J. W.) and **Brady** (M. P.).

Brocchi (M. P.) Note sur un crustacé fossile recueilli dans les schistes d'Autun.

In Bull. Soc. Géol. France, 3d series, vol. 8, No. 1, 1880, p. 3, pl. 1.

Palæocaris, Gampsonyx, Nectotelson n. g.

Brodie (P. B.) History of fossil insects in the Secondary rocks of England. London, 1845, pp. 105–115, pl. 1, fig. 11.

This author describes and figures a fossil from Coalbrookdale resembling the caterpillar of the Emperor moth, which was afterwards described by J. W. Salter under the name of *Eurypterus* (*Arthropleura*) *ferox.*

Brögger (W. C.) Fossiler fra Oxna og Kletten. (*)

In Geol. Föreningens Stockholm Förhandl., vol. 2, 1875, 1 pl.

Paradoxides, Liostracus, Agnostus.

—— Andrumkalk ved Breidengen valders.

In Geol. Föreningens Stockholm Förhandl., vol. 3, 1876, 1 pl.

Paradoxides, Liostracus, Selenopleura, Agnostus.

—— Om Trondhjemsfeldtets midlere Afdeling mellem Guldalen og Meldalen Christiania. (*)

In Vidensk. Selskab. Förhandl., 1877, No. 2, p. 1, 2 pls.

Dalmanites, Trinucleus.

—— Om Paradoxides skifrene ved Krekling. (*)

In Nyt Mag. Naturvid., vol. 24, pt. 1, 1878, 6 pls.

Paradoxides, Olenellus, Dolichometopus, Liostracus, Conocoryphe, Anomocare, Elyx, Solenopleura, Ellipsocephalus, Arionellus, Agnostus.

—— Die silurischen Etagen 2 und 3 im Kristianiagebiet und auf Eker. Kristiania, 1882, 12 pls.

Remopleurides, Dicelocephalus, Olenus, Parabolina, Peltura, Cyclognathus, Ceratopyge, Ctenopyge, Protopleura (new subgenus to the genus *Peltura*), *Parabolinella* (new subgenus to the genus *Olenus*), *Leptoplastus, Sphærophthalmus, Eurycare, Bæckia* n. g., *Triarthrus, Euloma, Holometopus, Harpides, Phacops, Lichas, Trinucleus, Ampyx, Asaphus, Megalaspis, Symphysurus, Niobe, Ptychopyge, Nileus, Cheirurus, Illænus, Dysplanus, Amphion, Cybele, Agnostus, Conophrys, Beyrichia, Leperditia, Isochilina.*

—— *Paradoxides ölandicus* nivået ved Ringsaker, Norge. (*)

In Geol. Föreningens Stockholm. Förhandl, vol. 6, 1884, 1 pl.

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Brögger (W. C.)—Continued.

—— Om aldern af Olenelluszonen i Nordamerika.

In Geol. Föreningens Stockholm Förhandl., vol. 8, 1886, p. 182.

—— Ueber die Ausbildung des Hypostomes bei einigen skandinavischen Asaphiden.

In Öfversigt Kongl. Svenska Vet.-Acad. Handl., vol. 11, 1886, 3 pls.

Asaphus, Isotelus, Ptychopyge, Megalaspis, Megalaspides n. g., *Niobe, Asaphellus, Ogygia, Nileus, Symphysurus.*

Bromell (M.) Lithographia Suecana.

In Acta Literaria Sueciæ, vol. 2, Upsaliæ, 1725, p. 63.

This work was continued in several parts through this volume, but it is only at p. 493, in the section called "De lapidibus insectiferis Scanices et Gothicis," that the Trilobites are treated. We have there the *Oleni* of the alum slate and *Agnostus pisiformis.*

A separate edition of the work was printed at Stockholm and Leipzig, in 1740, bearing the same title as the original work.

Brongniart (Alex.) Histoire naturelle des Crustacés fossiles sous les rapports zoologique et géologique, savoir les Trilobites. Les Crustacés proprement dits par A.-G. Desmarest. 11 pls. Paris, 1822.

This author was the first systematic writer upon the Trilobites. He arranges twenty-two species under five new generic names, as follows: First genus, *Calymene*, species 1. *C. de Blumenbach*, 2. *C. de Tristan*, 3. *C.? variolaire*, 4. *C.? macrophtalme.* Second genus, *Asaphus*, species 1. *A.? cornigère*, 2. *A. de Debuch*, 4. *A. caudigère*, 5. *A. large queue.* Third genus, *Ogygia*, species 1. *O. de Guettard*, 2. *O. de Desmarest.* Fourth genus, *Paradoxides*, species 1. *P. de Tessin*, 2. *P. spinuleux*, 3. *P. scaraboïde*, 4. *P.? gibbeux*, 5. *P. lacinie.* Espèces de genre incertain: *Trilobite granulé, T. ponctué, T. bucéphale, T. tentaculé.* Fifth genus, *Agnostus*, species 1. *A. pisiforme.*

—— and **Desmarest** (A.-G.) Histoire naturelle des Trilobites et des Crustacés fossiles.

In Jour. Mines, vol. 9, 1822, p. 273.

Bronn (Heinrich). Ueber zwei neue Trilobiten-Arten.

In Zeitschr. für Mineral., vol. 1, pt. 1, 1825, p. 317, pl. 2.

Calymene latifrons, C. schlotheimi.

—— Geognostische zoologische Untersuchungen in den russisch-baltischen Provinzen von Herrn Dr. Eduard Eichwald.

In Zeitschr. für Mineral., vol. for 1828, pt. 1, p. 104.

Bronn (H. G.) Lethæa geognostica, oder Abbildungen und Beschreibungen der für die Gebirgs-Formationen bezeichnendsten Versteinerungen. Stuttgart, 1835–'38.

2 vols., and atlas with 47 pls.

—— and **Roemer** (F.) H. G. Bronn's Lethæa geognostica, oder Abbildungen und Beschreibungen der für die Gebirgs-Formationen bezeichnendsten Versteinerungen. 3d ed. Stuttgart, 1851–'56.

3 vols. and atlas, 124 pls.; vol. 1, p. 525.

Harpes, Harpides, Remopleurides, Paradoxides, Hydrocephalus, Sao, Arionellus, Ellipsocephalus, Olenus, Conocephalites, Proetus, Cyphaspis, Phillipsia, Arethusina, Phacops, Dalmania, Orypl·æus. Calymene, Homalonotus, Lichas, Trinucleus, Ampyx, Dionide, Asaphus, Ogygia, Æglina, Illænus, Acidaspis, Ceraurus, Placoparia, Sphærexochus, Staurocephalus, Deiphon, Dindymene, Zetheis, Amphion, Encrinurus, Cromus, Bronteus, Telephus, Agnostus, Eurypterus, Himantopterus, Pterygotus, Limulus, Gampsonychus, Cythere, Bairdia, Cypridina, Cyprella, Entomoconchus, Beyrichia, Dithyrocaris, Ceratiocaris.

—— Note über die mit Homalonotus verwandten Trilobitengenera.

In Neues Jahrbuch für Mineral., 1840, p. 445, pl. 8, figs. 1 a, b.

—— Index palæontologicus, oder Uebersicht der bis jetzt bekannten fossilen Organismen, unter Mitwirkung der HH. H. R. Göppert und Herm. von Meyer bearbeitet von Dr. H. G. Bronn, Nomenclator palæontologicus in alphabetischer Ordnung. Stuttgart, 1848, 3 vols.

—— Ueber *Gampsonyx fimbricatus* Jordon aus der Steinkohlen-Formation von Saarbrücken und vom Murg-Thal.

In Neues Jahrbuch für Mineral., 1850, p. 575.

Brückmann (F. E.) Epistolarum itinerariarum centuria. Wolfenbüttelæ, 3 vols.

In Epist. 23, pl. 2, figs. 1–7, 1732, and Epist. 64, pl. 3, fig. 5, 1737.

This author compares the fossil Crustacea with the Mollusca and calls them *Armata veneris.*

Brunnich (M. T.) Beskrivelse over Trilobiten, en Dyrestagt og dens Arter, med en ny Aftegning.

In Nye Samling of det Kongelige Danske Vi, denskabers Selskabs Skriften, Kiöbenhavn, 1781, p. 384, 1 pl.

This author describes *Trilobus* (*Calymene*) *tuberculatus, Trilobus* (*Dalmanites*) *caudatus* (figures of head and pygidium), *Trilobus dilatatus, Trilobus* (*Encrinurus*) *punctatus.*

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Buch (Leopold von). Beiträge zur Bestimmung der Gebirgs-Formationen in Russland.

In Archiv mineral. Geogn., etc., vol. 15, Berlin, 1841, p. 1, pl. 2.

Phacops, Calymene, Asaphus, Illænus.

Buckland (William). Geology and mineralogy considered with reference to natural theology. Bridgewater treatise. 2 vols. London, 1837, 87 pls. [4th ed., London, 1869, 2 vols., 90 pls.]

Translated into German by L. Agassiz.

Paradoxides, Phillipsia, Phacops, Calymene, Asaphus, Ogygia, Encrinurus, Limulus (Belinurus) trilobitoides.

Burmeister (H.) Die Organisation der Trilobiten, etc. Berlin, 1843, 6 pls.

The English translation is entitled: "The organization of Trilobites deduced from their living affinities, with a systematic review of the species hitherto described, by Hermann Burmeister, edited from the German by Prof. Thomas Bell, F. R. S., and Prof. E. F. Forbes, F. R. S." London, Ray Society, 1846. There is a supplementary appendix by the editors.

Burmeister classifies 63 species under 23 genera arranged in the following order:

Eurypterus, Cytherina, Trinucleus, Ogygia, Odontopleura, Arges, Bronteus, Paradoxides, Olenus, Conocephalus, Ellipsocephalus. Harpes, Calymene, Homalonotus, Phacops, Cyphaspis n. g., *Proetus, Æonia* n. g., *Archegonus* n. g., *Illænus, Dysplanus* n. g., *Asaphus, Ampyx.*

The supplementary appendix by Thomas Bell and E. F. Forbes contains an alphabetical list of British Trilobites, also a copy of McCoy's generic description of the following genera: *Tiresia, Forbesia, Portlockia, Trinodus* (Synopsis Silurian Fossils Ireland, 1846); the generic descriptions of *Cheirurus, Sphærexochus, Lichas, Trochurus* (Beyrich, Ueber einige böhmische Trilobiten, 1845), and a list of the genera and species described by Barrande (Notice préliminaire sur le système silurien et les Trilobites de Bohême, 1846).

—— and **Alton** (Ed. de). Neue Beobachtungen über die Organisation der Trilobiten. (*)

In Zeitung für Zoologie, Zootomie und Palæozoologie, Alton und Burmeister, Leipzig, vol. 1, 1848, p. 67, pl. 1, figs. 13-19.

Callaway (Charles). On a new area of Upper Cambrian rocks in South Shropshire, with a description of a new fauna.

In Quart. Jour. Geol. Soc. London, vol. 33, 1877, p. 652, plate.

Olenus, Conocoryphe, Asaphus, Asaphellus (new subgenus), *Platypeltes* (new subgenus), *Lichapyge* n. g., *Agnostus, Conophrys* n. g.

Castelnau (Laport de). Communique à l'Académie des sciences de Paris la découverte des pieds des Trilobites qu'il aurait vus dans l'intérieur d'un exemplaire enroulé de l'Amérique du Nord.

In Inst. France, 1842, p. 74; Neues Jahrbuch für Mineral., 1843, p. 504; Comptes Rendus, vol. 14, 1842, p. 344.

Calymene.

—— Essai sur le système silurien de l'Amérique Septentrionale. Paris, 1843, 27 pls.

Asaphus microrurus, A. limulurus, A. cordieri, A. caudatus, A. edwardii, A. murchisoni, Homalonotus giganteus, H. herculaneus, H. atlas, Arctinurus n. g., *A. boltoni, Calymene bufo, Odontocephalus, Acantholoma, Aspidolites, Discranurus.*

Champernowne (A.) Note on a find of *Homalonotus* in Red Beds at Torquay.

In Geol. Mag., new series, decade 2, vol. 8, 1881, p. 487.

Chapman (E. J.) *Asaphus canadensis.*

In Canadian Jour., new series, vol. 1, 1856, p. 482.

—— A review of the Trilobites, their characters and classification.

In Canadian Jour., new series, vol. 1, 1856, p. 271, wood-cuts.

—— *Trinucleus concentricus.*

In Canadian Jour., new series, vol. 3, 1858, p. 414, wood-cut.

—— On some new Trilobites from Canadian rocks.

In Annals Mag. Nat. Hist., 3d series, vol. 2, 1858, p. 9, 2 figs.

Asaphus canadensis, A. halli.

—— On some new Trilobites from Canadian rocks.

In Canadian Jour., new series, vol. 3, 1858, p. 230, 2 wood-cuts.

Asaphus canadensis, A. halli.

—— On the hypostoma of *Asaphus canadensis* and on a third new species of Asaphus from the Canadian rocks.

In Canadian Jour., new series, vol. 4, 1859, p. 1, 2 figs.

Asaphus canadensis, A. hincksii.

—— On the probable nature of the supposed fossil tracks known as *Protichnites*, etc.

In Canadian Jour., new series, vol. 16, 1877, p. 7.

Clarke (J. M.) New Phyllopod Crustaceans from the Devonian of western New York.

In Am. Jour. Sci., 3d series, vol. 23, 1882, p. 476, plate.

Estheria, Spathiocaris n. g., *Liegocaris* n. g.

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Clarke (J. M.)—Continued.

—— Cirriped Crustacean from the Devonian.

In Am. Jour. Sci., 3d series, vol. 24, 1882, p. 55.
Plumulites devonicus.

—— New discoveries in Devonian Crustacea.

In Am. Jour. Sci., 3d series, vol. 25, 1883, p. 120.
Dipterocaris n. g.

—— Ueber deutsche oberdevonische Crustaceen (hierzu) Tafel 4.

In Neues Jahrbuch für Mineral., 1884, pt. 1, p. 178.
Spathiocaris, Entomis, Dithyrocaris.

—— On the higher Devonian fauna of Ontario County, New York.

In Bull. U. S. Geol. Survey, No. 16, 1885, 3 pls.
Ceratiocaris, Beyrichia, Echinocaris, Spathiocaris.

—— The structure and development of the visual area in the Trilobite *Phacops rana* Green.

In Jour. Morphology, vol. 2, No. 2, Nov., 1888, Boston, p. 253, pl. 21.

Clarke (W. B.) On the occurrence of Trilobites in New South Wales.

In Quart. Jour. Geol. Soc. London. vol. 4, 1848, p. 63 (not descriptive).

Claypole (E. W.) Note on a large Crustacean from the Catskill group of Pennsylvania.

In Proc. Am. Philos. Soc., Phila., vol. 21, 1883, p. 236, plate.
Dolichocephala n. g.

—— On the occurrence of the genus *Dalmanites* in the Lower Carboniferous rocks of Ohio.

In Geol. Mag., decade 3, vol. 1, London, 1884, p. 303.
Dalmanites? cuyahogæ.

Conrad (T. A.) Report on the Palæontological Department.

In Rept. Geol. Survey New York, 1838, p. 107.
Platynotus n. g.

—— On the Silurian system; with a table of the strata and characteristic fossils.

In Am. Jour. Sci., 1st series, vol. 38, 1840, p. 86.

—— Third Annual Report on the Palæontological Department of the Survey.

In Rept. Geol. Survey New York, 1840, p. 199.
Odontocephalus n. g., *Acanthaloma* n. g., *Odontocephalus selenurus, Asaphus halli, Acidaspis tuberculatus.*

—— Description of new genera and species of organic remains. Crustacea.

In Rept. Geol. Survey New York, 1841, p. 48, 1 pl.

Conrad (T. A.)—Continued.

Aspidolites n. g., *Dicranurus* n. g., *Asaphus? acantholeurus, A.? denticulatus, A. nasutus, A. aspectans, Calymene senaria.*

The plate accompanying this report was distributed with a few copies. Republished in the 15th Rept. New York State Cab. Nat. Hist., pl. 11.

—— *Cytherina alta.*

In Geol. Survey New York, pt. 3, comprising the survey of the 3d Geol. Dist. (Vanuxem), 1842, p. 112, fig. 23, No. 6.

—— Observations on the Silurian and Devonian systems of the United States, with descriptions of new organic remains.

In Jour. Acad. Nat. Sci., Phila., vol. 8, 1842, p. 228, 6 pls.
Asaphus corycæus, A.? trentonensis, Calymene spinifera, C. camerata, Dipleura.

—— Observations on the lead-bearing limestone of Wisconsin, and descriptions of a new genus of Trilobites and fifteen new Silurian fossils.

In Proc. Acad. Nat. Sci. Phila., vol. 1, 1843, p. 329.
Thaleops n. g.

Corda (A. J. C.) and **Hawle** (Ignaz). Prodrom einer Monographie der böhmischen Trilobiten.

In Abhandl. böhm. Gesell. Wiss., Prag, vol. 5, 1847, pp. 129–292, 7 pls.

This work is generally attributed to A. J. C. Corda. The 58 new genera described in this work are arranged by Joachim Barrande, Système silurien du centre de la Bohême, vol. 1, p. 39, as follows:

I. DIVISION. TELEJURIDES.

1. Phbysacium } = Hydrocephalus Barr.
2. Phanoptes }
3. Crithias
4. Tetracnemis
5. Goniacanthus
6. Enueacnemis
7. Acanthocnemis
8. Acanthogramma
9. Endogramma
10. Micropyge
11. Selenosema
12. Staurogmus
} = Sao Barr.
13. Herse } = Arionellus Barr.
14. Agraulos }
15. Conocoryphe
16. Ptychoparia
17. Ctenocephalus
} = Conocephalus Zenk.
18. Selenopeltis = Acidaspis Murch.
19. Polytomurus = Dionide Barr.
20. Tetrapsellium = Trinucleus Lhwyd.
21. Phalacroma = Agnostus (in part) Brong.
22. Selenoptychus = Æglina Barr.
23. Mesospheniscus = Agnostus integer Beyr.
24. Diplorrhina = Agnostus integer.

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Corda (A. J. C.) and **Hawle** (Ignaz)—Continued.

I. DIVISION. TELEJURIDES—Cont'd.

25. Condylopyge } = Agnostus rex Barr.
26. Lejopyge }
27. Microparia = Æglina Barr.
28. Plæsiacomia = Illænus Dalm.
29. Cyclopyge = Æglina (in part) Barr.
30. Alceste = Illænus (in part) Dalm.
31 Xiphogonium = Proetus Stein.
32. Conoparia = Cyphaspis Burm.
33. Goniopleura = Proetus elegantulus Ang.
34. Aulacopleura = Arethusina Barr.
35. Pharostoma = Calymene Brong.
36. Atractopyge } = Dalmania (in part) Emmrich.
37. Odontochile }

(This generic term was used in 1834 for a genus of the Coleoptera).

II. DIVISION. ODONTURIDES.

38. Amphytrion = Remopleurides Portlock.
39. Arthrorhachis = Agnostus tardus Barr.
40. Peronopsis = Agnostus integer Beyr.
41. Battus = Agnostus integer.
42. Pleuroctenium = Agnostus granulatus Barr.
43. Thysanopeltis = Bronteus (in part) Gold.
44. Dindymene = Dindymene Corda.
45. Prionopeltis = { Proetus (in part) Stein. Phætonides Barr.
46. Asteropyge } = Dalmania (in part) Dalm.
47. Metacanthus }
48. Odontopyge = Olenus spinulosus.
49. Placoparia = Placoparia Corda.
50. Ecoptochile = Cheirurus Beyr.
51. Actinopeltis = Cheirurus Beyr.
52. Trochurus = Staurocephalus Barr.
53. Corydocephalus } = Lichas Dalm.
54. Dicranopeltis
55. Acanthopyge
56. Dicranogmus
57. Trapelocera = Acidaspis Murch.
58. Ceratopyge = Olenus forficula Sars.

Cozzens (Issachar). Description of three new fossils from the Falls of the Ohio.

In Annals Lyceum Nat. Hist. New York, vol. 4, 1846, p. 157, 1 pl.

Piliolites n. g.

The author therein describes a species of *Proetus* under the name of *Piliolites ohioensis*.

Da Costa (E. M.) A letter concerning the fossil from Dudley.

In Philos. Trans. Royal Soc., vol. 48, pt. 1, No. 42, 1753, p. 286, pl. 1, figs. 6–8.

Dr. Da Costa herein gives the name of *Pediculus marinus major trilobus* to the then called Dudley fossils (*Calymene blumenbachii*), and declares it to be a crustaceous animal nearly related to the living *Isopodes*.

—— Description of a curious fossil animal.

In Gentleman's Mag., vol. 25, London, 1754, p. 24, pl. —, fig. 3.

Calymene blumenbachii.

Dalman (J. W.) Några petrificater fundne i Ostergötlands ofvergangskalk afterknade och beskrifne.

In Svenska Vetensk. Akad. Handl., 1824, p. 368, pl. 4.

Entomostr. actinurus.

—— Om Palæaderna eller de sa kallade Trilobiterna. Stockholm, 1826, 6 pls.

Svenska Vetensk. Akad. Handl., 1826, p. 226.

The German translation bears the following title: Ueber die Palæaden, oder die sogenannten Trilobiten von J. D. Dalman, von Friedrich Engelhart, mit 6 Kupfertafeln, Nürnberg, 1828.

Dalman arranges 41 species of Trilobites under 5 genera and 4 subgenera, as follows:

Division I. Oculated: 1st genus, *Calymene;* 2d genus, *Asaphus*.

Division II. Typhlini: 3d genus, *Ogygia;* 4th genus, *Olenus* (*Paradoxides* Br.). Section 2. Battoides: 5th genus, *Battus* (*Agnostus* Br.).

Subgenera: 1. *Asaphus* (*Nileus*); 2. *Asaphus* (*Illænus*); 3. *Asaphus* (*Ampyx*); 4. *Lichas* n. g.

—— Årsberättelse om nyare zoologiska arbeten och upptäckter.

This work forms a part of the annual report of the keepers of the Swedish State Museum for 1828. It contains (p. 134), under the title of "Nya Svenska Palæades" a description of the following Trilobites: *Calymene ornata, C. verrucosa, C. clavifrons, C.? centrina, Asaphus heros, A. platynotus, Nileus glomerinus, Ampyx pachyrrhinus, Battus lævigatus, B. pisiformis*.

—— Nouvelles espèces de Trilobites ou Palæades de Suède.

In Bull. Férussac, vol. 19, 1828, p. 129.

A notice of the preceding reference.

Dames (W.) Ueber *Hoplolichas* und *Conolichas*, zwei Untergattungen von *Lichas*.

In Zeitschr. Deutsch. geol. Gesell., Berlin, 1877, vol. 29, pt. 1, p. 793, 3 pls.

The type used for the new genus *Hoplolichas* is *Lichas tricuspidatus* Boll, and for *Conolichas*, *Lichas æquiloba* Steinh.

—— Geologische Reisenotizen aus Schweden.

In Zeitschr. Deutsch. geol. Gesell., Berlin, 1881, vol. 33, p. 405.

Paradoxides œlandicus, P. tessini, P. forchhammeri, P. kjerulfi, Ellipsocephalus, Lichas, Megalaspis, Asaphus?, Agnostus.

—— Erste Abhandlung. Cambrische Trilobiten von Lian Tung, China (Richthofen). Vol. 4. Berlin, 1883, pls. 1, 2.

The author suggests the new generic term *Dorypyge* for certain Trilobites which have the pygidium armed with strong spines, the penultimate pair being the longest, including in the genus *Dikelocephalus quadriceps* Hall and Whitfield and *D. gothicus* Hall and Whitfield.

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Dames (W.)—Continued.

Under *Anomocare* Angelin he includes the following American species: *Conocephalites hamulus* Owen, *C. wisconsinensis* Owen, and *C. pattersoni* Hall.

Conocephalites frequens, C. quadriceps, C. typus, C. subquadratus, Anomocare latelimbatum, A. minus, A. planum, A. nanum, A. majus, A. subcostatum, Liostracus talingensis, L. megalurus, Dorypyge n. g., *D. richthofeni, Agnostus chinen.*

—— E. W. Claypole: On the occurrence of the genus Dalmanites in the Lower Carboniferous rocks of Ohio. Geol. Mag. London, 1884.

In Neues Jahrbuch für Mineral., 1885, vol. 1, p. 102 (abstract).

Dalmanites, Phillipsia, Proetus.

—— C. D. Walcott: Appendages of the Trilobites. Science, vol. 3. 1884, p. 279.

In Neues Jahrbuch für Mineral., vol. 1, p. 102 (abstract).

Asaphus, Calymene, Ceraurus.

—— T. R. Jones and J. W. Kirkby: On some Carboniferous Entomostraca from Nova Scotia. Geol. Mag. London, 1884.

In Neues Jahrbuch für Mineral., vol. 1, 1885, p. 106 (abstract).

Leperditia, Beyrichia.

—— T. R. Jones and H. Woodward: Notes on Phyllopdiform Crustacea, referable to the genus *Echinocaris* from the Palæozoic rocks. Geol. Mag. London, 1884.

In Neues Jahrbuch für Mineral., vol. 1, 1884, p. 110 (abstract).

—— Chas. E. Beecher: Ceratiocaridæ from the Chemung and Waverly group of Warren County. Second Geol. Survey, Penn. Rept. PPP.

In Neues Jahrbuch für Mineral., vol. 1, 1884, p. 110 (abstract).

—— J. Mickleborough: Locomotory appendages of Trilobites. Geol. Mag. London, 1884.

In Neues Jahrbuch für Mineral., 1885, p. 477.

—— F. Schmidt and T. R. Jones: On some Silurian *Leperditia*. Annals Nat. Hist., series 5, vol. 9, 1882, p. 168.

In Neues Jahrbuch für Mineral., 1885, vol. 1, p. 105 (abstract).

Dana (James D.) Trilobites in the Potsdam sandstone.

In Edinburgh New Philos. Jour., vol. 6, 1857, p. 350.

—— On the supposed legs of Trilobites (*Asaphus platycephalus*).

In Annals Nat. Hist., 4th series, vol. 7, London. 1871, p. 366; Am. Jour. Sc., 3d series, vol. 1, 1871, p. 320.

Dana (James D.)—Continued.

—— Manual of geology, treating of the principles of the science with special reference to American geological history. 2d ed. New York, 1874, p. 174.

D'Archiac (A.) and **Verneuil** (E. de). On the fossils of the older deposits in the Rhenish Provinces, preceded by a general survey of the fauna of the Palæozoic rocks, and followed by a tabulated list of the fossils of the Devonian system of Europe.

In Bull. Soc. Géol. France, vol. 13, 1841-'42; Trans. Geol. Soc. Lond., vol. 6, pt. 2, 1842, p. 303.

——, **Fischer** (de Waldheim G.) and **Verneuil** (E. de). Paléontologie de l'Asie Mineure. Paris, 1866, atlas, 21 pls. (*)

Dawson (J. W.) On the Lower Coal Measures as developed in British America.

In Quart. Jour. Geol. Soc. London, vol. 15, 1859, p. 62.

Tracks of a Crustacean.

—— Note on the fossils of Nova Scotia.

In Canadian Naturalist, vol. 5, 1860, p. 297 (wrongly paged 197 in the volume).

Homalonotus dawsoni Hall.

—— On the foot prints of *Limulus* as compared with the *Protichnites* of the Potsdam sandstone.

In Canadian Naturalist, vol. 7, 1862, p. 271 Am. Jour. Sci., 2d series, vol. 34, 1862, p. 416.

—— Acadian geology. The geological structure, organic remains, and mineral resources of Nova Scotia, New Brunswick, and Prince Edward Island, etc. London.

Three editions, 1855-'78 (3d ed. contains the supplement to the 2d ed.).

Paradoxides, Conocephalites, Phillipsia, Dalmanites, Agnostus, Microdiscus.

Mr. C. F. Hartt's descriptions of the trilobites first appeared in the third edition of this work. The original MSS. described *Microdiscus dawsoni* under the new generic name of *Dawsonia*, but on Prof. E. Billings's authority the author has referred it to *Microdiscus dawsoni.*

Eurypterus, Estheria, Leaia, Beyrichia, Leperditia, Cythere, Diplostylus.

—— Supplement to the 2d edition of Acadian geology. Containing additional facts as to the geological structure, fossil remains, and mineral resources of Nova Scotia, New Brunswick, and Prince Edward Island. London, 1878.

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Dawson (J. W.)—Continued.

Homalonotus dawsoni, *Protichnites carbonarius*, *Anthracopalæmon* (*Palæocarbus*) *hillianum*.

—— Note on two Palæozoic Crustaceans from Nova Scotia.

In Geol. Mag., decade 2, vol. 4, London, 1877, p. 56. (See, also, Supplement Acadian Geol., 1878, p. 55, fig. 10.)

Anthracopalæmon (*Palæocarabus*) *hillianum*, *Homalonotus dawsoni*.

Day (F. H.) On the fauna of the Niagara and Upper Silurian rocks as exhibited in Milwaukee County, Wisconsin, and in counties contiguous thereto.

In Trans. Wisconsin Acad. Sc., vol. 4, 1876–'77, p. 113.

Dekay (J. E.) Observations on the structure of Trilobites, and description of an apparently new genus; with notes on the geology of Trenton Falls, by James Renwick. Read Nov. 22 (1824).

In Annals Lyceum Nat. Hist., New York, vol. 1, 1824. p. 174, 2 pls.; Isis (oder Encycl. Zeitung), Oken, 1825 and 1832.

Isotelus n. g.

—— Observations on a fossil crustaceous animal of the order Branchiopoda. Read Dec. 12, 1825.

In Annals Lyceum Nat. Hist., New York, vol. 1, pt. 2, p. 375, pl. 29. Republished in Harlan's Med Phys. Researches, 1835, p. 297.

Eurypterus n. g.

—— Report on several fossil multilocular shells from the State of Delaware; with observations on a second specimen of the new fossil genus Eurypterus. Read Oct. 2, 1827.

In Annals Lyceum Nat. Hist., New York, vol. 2, 1828, p. 273.

Deslongchamps (E.) Mémoire sur les corps organisés fossiles du grès intermédiaire du Calvados.

In Soc. Linn. Calvados, vol. 2, 1825, p. 291, 2 pls.

The author herein describes two species of the genus *Homalonotus* under the names *Asaphus brongniarti* and *A. brevicaudatus*.

Dethleff (von) and **Boll** (Ernst). Die Trilobiten Mecklenburgs.

In Archiv Vereins Freunde Naturg. Mecklenburg, 1858, p. 155.

Remopleurides, *Paradoxides*, *Ellipsocephalus*, *Olenus*, *O.* (*Sphærophthalmus*), *Proetus*, *Cyphaspis*, *Harpides*, *Phacops*, *Calymene*, *Homalonotus*, *Lichas*, *Trinucleus*, *Ampyx*, *Asaphus*, *Ogygia*, *Illænus*, *Nileus*, *Acidaspis*, *Cheirurus*, *Sphærexochus*, *Sphærocoryphe*, *Amphion*, *Encrinurus*, *Bronteus*, *Telephus*, *Holometopus*, *Dolichometopus*, *Agnostus*.

Devine (T.) Description of a new Trilobite from the Quebec group.

In Canadian Naturalist, vol. 8, 1863, p. 95, 2 figs.

Loganellus n. g.

Similar forms have been referred by Corda to the genus *Ptychoparia*.

—— Description of a new Trilobite from the Quebec group.

In Canadian Naturalist, vol. 8. 1863, p. 210, fig.

Menocephalus salteri.

Dewalque (G.) Prodrome d'une description géologique de la Belgique. Bruxelles, 1868; 2d ed., 1880.

Contains important list of fossils, and observations.

Dumont (A.-H.) Mémoire sur la constitution géologique de la province de Liège.

In Mém. Cour. Acad. Roy. Sci., Bruxelles, vol. 8, 1832, p. 353. Table of fossils.

Durocher (J.) Sur le test des Trilobites et des animaux fossils de la Bretagne en général.

In Bull. Soc. Géol. France, 2d series, vol. 7, p. 307, also vol. 8, 1850–'51, p. 160.

Dwight (W. B.) Recent explorations in the Wappinger Valley limestone of Dutchess County, New York.

In Am. Jour. Sci., 3d series, vol. 27, 1884, p. 349, pl. 7.

Bathyurus.

Eaton (Amos). Geological Equivalents.

Description of *Ogygies latissimus* and *Cancer trilobioides*.

In Am. Jour. Sci., 1st series, vol. 21, 1832, pp. 135, 136, note.

Cancer trilobioides, *Oxygies*.

—— Trilobites.

Am. Jour. Sci., 1st series, vol. 22, 1832, p. 165.

Brongniartia n. g.

We learn from reference to Dr. Amos Eaton's description and figures given in his "Geological text-book," p. 33, pl. 1, fig. 3 (2d ed., 1832), that the original of *Brongniartia carcinodea* Eaton was the same as that afterwards described by Dr. Jacob Green (Monthly Am. Jour Geology, vol. 1, June, 1832; also Mon. Tril. N. A., p. 87, pl. 1, fig. 6, cast 34) as *Triarthrus becki*.

—— Geological text-book for aiding the study of North American geology; being a systematic arrangement of facts collected by the author for his pupils, etc. 2d ed., 5 pls. (June 15, 1832).

The following species are described in this work, pp. 31–34: Genus *Calamena*, *C. blumenbachii* (*Calymene senaria* Conrad), pl. 2, fig. 19; genus *Asaphus*, *A. hausmannii*, *A. caudatus* (*Dalmanites limulurus* Green), pl. 2, fig. 18; *A. selenourus* (*Dalmanites selenurus* Eaton), pl. 1,

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Eaton (Amos)—Continued.

fig. 1; genus *Brongniartia*, *B. platycephala* (*Homalonotus dekayi* Green), pl. 2, fig, 20; *B. isotelea* (*Asaphus platycephalus* Stokes), pl. 2, fig. 22; *B. carcinodia* (*Triarthrus beckii* Green), pl. 1, fig. 3; genus *Nuttainia*, *N. concentrica* (*Trinucleus concentrica* Eaton), pl. 1, fig. 2; *N. sparsa* (*Homalonotus dekayi* Green).

Eichwald (Eduard). Observationes geognostico-zoologicæ per Ingriam marisque Baltici Provincias nec non de Trilobites. Casani, 1825, 4 pls.

The author herein describes and figures eight species of Lower Silurian Trilobites under the new generic term *Cryptonymus*. In his later work ("Lethœa Rossica," p. 1449) the first three are referred to the genus *Asaphus*; viz, *Cryptonymus schlotheimii* to *Asaphus schlotheimii*, *Cryp. weissii* to *Asaphus weissii*, *Cryp. panderi* to *Asaphus expansus* Wahl. The last five are classed as follows: *Cryp. lichtensteinii* under *Niobe lichtensteinii*, *Cryp. rosenbergii* to *Illænus rosenbergii*, *Cryp. wahlenbergii* to *Illænus wahlenbergii*, *Cryp. rudolphii* to *Illænus rudolphii*, *Cryp. parkinsonii* to *Illænus parkinsonii*.

This work also contains a description and a figure of *Asaphus fischeri* (*Amphion fischeri* Eich.).

The description of two new Carbonic Trilobites are added by Dr. G. Fischer, pp. 53–55, pl. 4, figs. 4 and 5, *Asaphus brongniarti*, pl. 4, fig. 5, and *A. eichwaldi*, pl. 4, fig. 4. Valerian von Möller ("Ueber die Trilobiten der Steinkohlenformation des Ural," 1867, p. 7) refers these species to *Phillipsia eichwaldi* Fisch., applying the term to the non-mucronate pygidium. The Russian mucronate species, figured by Eichwald ("Lethœa Rossica," pl. 54, fig. 10) as *Griffithides eichwaldi*, was assigned by the same author to *Phillipsia mucronata* McCoy.

—— Zoologia specialis, quam expositis animalibus tum vivis tum fossibilibus postissernum Rossiæ in Universum et Poloniæ. Vilnæ, vols. 1–3, 1829–'31. (*)

—— Die Thier- und Pflanzenreste des alten rothen Sandsteins und Bergkalk in Novgorodischen Gouvernement.

In Bull. Acad. Petropol. St. Petersburg, vol. 7, 1840, p. 78.

Otarion eichwaldi.

—— Ueber das silurische Schichten-System von Ehstland. St. Petersburg, 1840.

Krustazeen, p. 64.

Calymene odini, *C. blumenbachii* Brong., *C. downingia* Murch., *C. macrophthalma* Murch., *C. bellatula* Dalm., *C. sembnitzkii*, *Amphion* (*Asaphus*) *fischeri*, *Zethus verrucosus* Pander, *Cryptonymus punctatus* (Wahl.) Eichwald, *C. variolaris*, *C. wörthii*, *Asaphus expansus* Wahl., *A. weissii*, *A. schlotheimii*, *A. latus* Pander, *A. laceniatus* Dalm., *A. dilatatus* Dalm., *A. devexus*, *A. tyrannus* Murch., *A. vulcani* Murch., *Illænus crassicauda* Dalm., *I. rosenbergii*, *I. cornutus* Pander, *I. perovatis* Murch., *I. centrotus* Dalm., *Trinucleus sparskii*, *Homalonotus herschelii* Murch., *Nileus armadillo* Dalm., *Agnostus nasutus* Dalm.

—— Die Urwelt Russlands durch Abbildungen erläutert.

4 pts., St. Petersburg, 1840–'48, 14 pls.

In the first part of this work, in the list of fossils given, p. 22, Eduard von Eichwald refers three species to *Cryptonymus*; a generic name which he used in 1825 for an entirely different series of fossil crustacea. In the present work he substitutes the name for such species as *Calymene variolaris*, *C. punctatus*, *C. worthi*, etc. The name is used without a generic description, and only indicated by the above named species.

Metopias n. g., pt. 2, p. 64, pl. 3, fig. 4.

—— Beiträge zur Geologie und Palæontologie Russlands. Moscau, 1854.

Bunodes n. g.

—— Die Grauwacken Schichten von Liv- und Estland.

In Bull. Soc. Imp. des Naturalistes Moscou, vol. 27, 1854, no. 1, p. 3.

Eurypterus, *Pterygotus*, *Bunodes*, *Sphagodus*.

—— Ueber die Gattungen *Cryptonymus* und *Zethus*.

In Bull. Soc. Imp. des Naturalistes Moscou, vol. 28, 1855. Separate ed., Moscou, 1855, 23 pp.

The author maintains that the genus *Cryptonymus* should be retained for several Russian and Swedish Trilobites as defined by N. P. Angelin ("Palæont. Scand.," 1852, p. 2), with *Calymene punctatus* as its type.

—— Beiträge zur geographischen Verbreitung der fossilen Thiere Russland's.

In Bull. Soc. Nat., Moscou, vols. 28–30, 1855–'57 (vol. 30, 1857).

Harpes, *Proetus*, *Cyphaspis*, *Homalonotus*, *Calymene*, *Griffithides*, *Phacops*, *Chasmops*, *Odontochile*, *Lichas*, *Trinucleus*, *Ampyx*, *Asaphus*, *Ptychopyge*, *Megalaspis*, *Nileus*, *Illænus*, *Dysplanus*, *Cheirurus*, *Sphærexochus*, *Amphion*, *Cryptonymus*, *Bronteus*, *Lonchodomas*, *Raphiophorus*, *Zethus*, *Sphærocoryphe*, *Eurypterus*, *Pterygotus*, *Beyrichia*, *Bairdia*.

—— Lethæa Rossica, ou paléontologie de la Russ. Stuttgart, 1852–'69. 3 vols., with atlas, 113 pls.

The Crustacea are arranged in the following order: First order, Ostracopodia, first family, Cypridina, genus 1. *Leperditia*, 2. *Bairdia*, 3. *Beyrichia*. Second order, Pœcilopoda, second family, Agnostidæ, genus 4. *Agnostus*. Third order, Copépoda, third family, Eurypteridæ, genus 5. *Eurypterus*, 6. *Pterygotus*. Fourth order, Xiphosuridæ, fourth family, Limulidæ, genus 7. *Campylocephalus* n. g. Fifth order, Isopodes, Trilobites, family Harpidæ, genus 8.

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Eichwald (Eduard)—Continued.

Harpes, 10. *Trinucleus*, 11. *Ampyx*, 12. *Lonchodomas*, 13. *Raphiophorus;* sixth family, Lichidæ, genus 14. *Lichas;* seventh family, Cheiruridæ, genus 15. *Acidaspis*, 16. *Ceraurus*, 17. *Sphærexochus*, 18. *Zethus*, 19. *Sphærexocoryphe;* eighth family, Amphionidæ, genus 20. *Amphion*, 21. *Homalonotus*, 22. *Cryptonymus;* ninth family, Calyminidæ, genus 23. *Calymene*, 24. *Acaste*, 25. *Phacops*, 26. *Chasmops*, 27. *Proetus*, 28. *Griffithides*, 29. (not given), 30. *Cyphasis;* tenth family, Remopleuridæ, genus 31. *Bunodes*, 32. *Pseudoniscus*, 33. *Remopleurides;* eleventh family, Asaphidæ, genus 34. *Asaphus*, 35. *Megalaspis*, 36. *Niobe*, 37. *Ptychopyge*, 38. *Ogygia*, 39. *Illænus*, 40. *Rhodope*, 41. *Dysplanus*, 42. *Actinobolus*, 43. *Nileus;* twelfth family, Brontidæ, genus 44. *Bronteus*.

—— Beiträge zur nähern Kenntniss der in meiner Lethæa Rossica beschriebenen Illænus, etc.

In Bull. Soc. Imp. des Naturalistes Moscou, 1863, No. 4, p. 372.

Nileus, *Bumastus*.

Emerson (B. K.) On the geology of Frobisher Bay and Field Bay.

Appendix 3. Narrative of the second Arctic expedition made by Charles F. Hall, 45th Cong., 3d sess., Senate Doc. 27, Washington, 1879.

Triarthrus, *Cyphaspis*, *Phacops*, *Calymene*, *Asaphus*, *Beyrichia*, *Leperditia*, *Primitia*.

Emmons (Ebenezer). Geology of New York. Pt. 2. Comprising the survey of the Second Geological District. Albany, 1842.

Isotelus gigas, fig. 99 (1); *Bumastus trentonensis*, fig. 100 (1); *Calymene senaria*, fig. 100 (2); *Illænus trentonensis*, fig. 100 (3); *Ceraurus pleurexanthus*, fig. 100 (6); *Trinucleus tessellatus*, fig. 100 (7); *Triarthrus beckii*, fig. 110 (1); *Trinucleus caractaci*, fig. 112 (1).

—— The Taconic system, based on observations in New York, Massachusetts, Maine, Vermont, and Rhode Island. Albany, 1844, 6 pls. and map.

Atops trilineatus n. s. and genus, fig. 8; *Elliptocepala asaphoides* n. s. and genus (not *Ellipsocephalus* Zenker, 1833), fig. 9.

—— Agriculture of New York, comprising an account of the classification, composition, and distribution of the soils and rocks, etc. Vol. 1. Albany, 1846, 21 pls. and maps.

Atops trilineatus, fig. 8; *Elliptocephala asaphoides*, fig. 9.

—— On the identity of the *Atops trilineatus* and the *Triarthrus beckii* Green, with remarks upon the *Elliptocephalus asaphoides*.

Emmons (Ebenezer)—Continued.

In Proc. Am. Assoc. Adv. Sci., First meeting, Philadelphia, 1848.

Atops trilineatus, *Triarthrus beckii*, *Eliptocephalus asaphoides*.

—— American geology, containing a statement of the principles of the science, with full illustrations of the characteristic fossils. Vol. 1, Parts I, II, and III. Albany, 1855–'57, atlas, 17 pls.

Dikelocephalus, *Olenus*, *Triarthrus*, *Atops*, *Conocephalus*, *Elliptocephalus*, *Phacops*, *Calymene*, *Trinucleus*, *Isotelus*, *Ogygia*, *Illænus*, *Acidaspis*, *Ceraurus*, *Agnostus*, *Microdiscus* n. g., *Beyrichia*, *Cytherina*, *Cyproides*.

—— Manual of geology, designed for the use of colleges and academies. New York, 1860.

Paradoxides? quadrispinosus, fig. 57; *Paradoxides macrocephalus*, fig. 70; *Atops punctatus*, fig. 71; *Microdiscus quadricostatus*, fig. 73; *Calymene senaria*, fig. 87; *Illænus trentonensis*, fig. 89 (a); *Illænus crassicauda*, fig. 89 (b); *Triarthrus beckii*, figs. 89 (c) and 91; *Isotelus gigas*, fig. 89 (d); *Beyrichia*, *Cytherina*, *Cyproides*, fig. 90; *Trinucleus caractaci*, fig. 93 (1); *Hemicriptturus*, fig. 97 (2); *Illænus barriensis* fig. 98 (3); *Dalmania selenurus*, fig. 118 (1); *Phacops bufo*, fig. 124 (6); *Dalmania calliteles*, fig. 124 (7); *Phacops nupera*, fig. 138 (2); *Cyphaspis girardeauensis*, fig. 145 (2); *Homalonotus dekayi*, figs. 134, 135.

Note A, p. 280, the author remarks: "We now know the following trilobites, all of which belong to a slate beneath the Calciferous; viz, *Atops punctatus*, *Eliptocephalus* (*Paradoxides*) *asaphoides*, *Paradoxides thompsoni*, *P. vermonti*, *P. macrocephalus*, *Paradoxides* (*Pagura*) *quadrispinosus*, and *Microdiscus quadricostatus*."

Dr. E. Emmons uses the name *Pagura* as a subgenus to *Paradoxides* without indicating his intention with regard to the genus. He may have intended it to replace the generic name of *Peltura* (*Olenus*) *holopyga* Hall, 12th Rept. New York State Cab. Nat. Hist., p. 61, which in the 13th Rept. New York State Cab. Nat. Hist., p. 118, is used for the type of *Bathynotus* Hall, 1860.

The preface of the manual is dated Raleigh, May 1, 1859.

Emmrich (H. F.) De Trilobitis dissertatio petrefactologica quam consensu et auctoritate amplissimi philosophorum ordinis, etc. Berolini, 1839, 1 pl.

Classifies 65 species and 9 genera and 6 subgenera, as follows:

1. Phacops.
2. Asaphus { Sec. 1. Ogygia. 2. Asaphus. 3. Illænus. 4.
3. Calymene { Sec. 1. Calymene. 2. Trimerus.

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Emmrich (H. F.)—Continued.

4. Depleura.
5. Conocephalus.
6. Ellipsocephalus.
7. Ampyx.
8. Paradoxides.
9. Odontopleura.
10. Cyphæus.

—— Zur Naturgeschichte der Trilobiten. Programm zur öffentlichen Prüfung, welche mit den Zöglingen der Realschule in Meiningen Donnerstag dem 28. und Freitag den 29. März 1844 im grossen Hörsaale der Anstalt abgehalten werden soll, etc. Meiningen, 1844, 1 pl.

Pt. 1. Zur Morphologie der Trilobiten, pp. 4–13.

Pt. 2. Ueber die Trilobitengattungen, pp. 13–18.

Pt. 3. Ueber die Verbreitung der Trilobiten in den Gebirgsschichten, pp. 18–28.

The genera are arranged into 25 families in the following order:

1. *Phacops*, *Dalmania* n. g., 2. *Phillipsia*, 3. *Griffithides*, 4. *Gerastos*, 5. *Asaphus*, 6. *Illænus*, 7. *Ogygia*, 8. *Bronteus*, 9. *Nuttania*, 10. *Encrinurus* n. g., 11. *Amphion*, 12. *Calymene*, 13. *Homalonotus*, 14. *Conocephalus*, 15. *Ellipsocephalus*, 16. *Anthes*, 17. *Paradoxides*, 18. *Odontopleura*, 19. *Arges*, 20. *Cryptolithus*, 21. *Ampyx*, 22. *Olenus*, 23. *Remopleurides*, 24. *Ceraurus*, 25. *Agnostus*.

—— Ueber die Trilobiten.

In Neues Jahrbuch für Mineral., 1845, p. 18, 1 pl.

For list of genera, see preceding reference.

—— On the morphology, classification, and distribution of the Trilobites.

Scientific Memoirs, edited by Richard Taylor, vol. 4, 1846, pt. 14, p. 253, 1 pl.

Translation of the preceding reference.

Esmark (H. M. T.) Om nogle nye Arten af Trilobiter. (*)

In Mag. for Naturvidensk., andre Række, Christiania, vol. 1, 1833, p. 268, pl. 8.

Trilobiter asellus, *T. elliptifrons*, *T. sphærius*, *T. semilunaris*, *T. dentatus*.

Etheridge (Robert). Description of the Palæozoic and Mesozoic fossils of Queensland.

In Quart. Jour. Geol. Soc. London, vol. 28 1872, p. 317.

Griffithides dubius, pl. 18, fig. 7.

—— Memoirs Geological Survey of Scotland. Edinburgh, 1873.

Expl. Map 23, p. 93.

Ceratiocaris.

—— Observations on a few Graptolites from the Lower Silurian rocks of Victoria, Australia, with a further note on the structure of Ceratiocaris.

In Annals Mag. Nat. Hist., London, 4th series, vol. 14, 1874, p. 1.

—— On the remains of a large Crustacean probably indicative of a new species of *Eurypteridæ*, or allied genus (*Eurypterus stevensoni*), from the Lower Carboniferous series (Cementstone group) of Berwickshire.

In Quart. Jour. Geol. Soc. London, vol. 33, 1877, p. 223, 2 figs.

—— Palæontology of the coasts of the Arctic lands visited by the late British expedition under Capt. Sir George Nares, etc.

In Quart. Jour. Geol. Soc. London, vol. 34 1878, p. 569.

Proetus, *Calymene*, *Asaphus*, *Encrinurus*, *Bronteus*.

—— On the occurrence of the genus *Dithyrocaris* in the Lower Carboniferous or Calciferous sandstone series of Scotland, and on that of a second species of *Anathrapalæmon* in these beds.

In Quart. Jour. Geol. Soc. London, vol. 35, 1879, p. 464, pl. 23.

Dithyrocaris, *Anthrapalæmon*.

—— On the occurrence of a small new Phyllopod Crustacean, referable to the genus *Leaia* in the Lower Carboniferous rocks of Edinburgh.

In Annals Mag. Nat. Hist., London, 5th series, vol. 3, 1879, p. 257.

—— and **Nicholson** (H. A.) See **Nicholson** (H. A.) and **Etheridge** (Robert).

—— and **Salter** (J. W.) See **Salter** (J. W.) and **Etheridge** (Robert).

—— Notes on a collection of fossils from the Palæozoic rocks of New South Wales.

In Proc. Royal Soc. New South Wales, vol. 19, 1880, p. 247, 1 pl.

Encrinurus punctatus.

—— Address of the President.

In Quart. Jour. Geol. Soc. London, vol. 37, 1881, p. 37.

—— Reports of the committee, consisting of Mr. R. Etheridge, Dr. Henry Woodward, and Prof. T. Rupert Jones, secretary, on the fossil Phyllopoda of the Palæozoic rocks.

See Reports of the secretary, recorded under **Jones** (T. Rupert). See, also, **Woodward** (Henry) and **Etheridge** (Robert); **Huxley** (T. H.) and **Etheridge** (Robert).

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Etheridge, jr. (Robert). On the occurrence of a macrurous decaped (*Anthraplæmon woodwardi* sp. nov.) in the Red Sandstone or lowest group of the Carboniferous formation of the southeast of Scotland.

In Quart. Jour. Geol. Soc. London, vol. 33, 1877, p. 863, pl. 27.

—— On *Pinnocaris lapworthi*.

Proc. Royal Phys. Soc., 1878, vol. 4, p. 167.

Pinnocaris n. g.

——. On the genus *Conocephalites*.

In Proc. Royal Soc. Tasmania, June, 1882, p. 152.

Feistmantel (Ottokar). Ueber ein neues Vorkommen von nordischen silurischen Diluvilgeschieben bei Lampersdorf in der Grafschaft Glatz (Zeitschrift Lotos, Dec., 1874, p. 10, Prag).

Phacops downingiæ, Leperditia marginata.

Fischer (G. de Waldheim). Notice sur l'Eurypterus de Podolie et le Chirotherium de Livonie. Moscou, 1839, 2 pls.

Eurypterus remipes, E. lacustris?, E. tetragonophthalmus n. s.

Fitch (Asa). Fossils of Washington County, New York.

In Trans. New York Agric. Soc., vol. 9, 1850, p. 862.

Atops trilineatus, Olenus asaphoides, Trinucleus concentrica.

Fletcher (W. F.) Observations on Dudley Trilobites.

In Quart. Jour. Geol. Soc. London, vol. 6, 1850, p. 235, pls. 27, 27 *bis*.

Lichas bucklandi, L. hirsutus, L. grayii, L. salteri, L. barrandii.

—— Observations on Dudley Trilobites. Part 2.

In Quart. Jour. Geol. Soc. London, vol. 6, 1850, p. 492, pl. 32.

Cybele punctata, C. variolaris.

Foerste (A. F.) The Clinton group of Ohio.

In Bull. Denison Univ., vol. 1, 1885, p. 65, 2 pls.

Acidaspis Bathyurus?, Illænus, Calymene, Lichas, Arionellus?, Dalmanites.

—— The Clinton group of Ohio. Pt. 2.

In Bull. Denison Univ., vol. 2, 1887, p. 89, pl. 8.

Proetus, Phacops, Dalmanites, Calymene, Lichas, Illænus, Acidaspis, Ceraurus, Encrinurus.

—— Note on Illæni.

In Fifteenth Rept. Geol. Nat. Hist. Survey Minnesota, 1886, p. 478.

Illænus minnesotensis, I. herricki, I. ambiguus, I. insignis Hall.

Foerste (A. F.)—Continued.

—— Notes on Palæozoic fossils. Pt. 2.

In Bull. Denison Univ., vol. 3, pt. 2, 1888, p. 117, pl. 13.

Phacops, Lichas, Sphærexochus, Encrinurus, Microdiscus.

Forbes (Edward). Description of *Ampyx nudus*.

In Mem. Geol. Survey United Kingdom, decade 2, London, 1849, pl. 2.

Ampyx nudus, Brachampyx n. g.

Ford (S. W.) Description of some new species of Primordial fossils.

In Am. Jour. Sci., 3d series, vol. 3, 1872, p. 419.

Agnostus nobilis.

—— Descriptions of new species of fossils from the Lower Potsdam group at Troy, New York.

In Am. Jour. Sci., 3d series, vol. 6, 1873, p. 137.

Microdiscus speciosus, Leperditia troyensis.

—— Note on the discovery of a new locality of Primordial fossils in Rensselaer County, New York.

In Am. Jour. Sci., 3d series, vol. 9, 1875, p. 204.

Conocephalites (*Atops*) *trilineatus* Emmons.

—— On additional species of fossils from the Primordial of Troy and Lansingburg, Rensselaer County, New York.

In Am. Jour. Sci., 3d series, vol. 11, 1876, p. 369.

Microdiscus meeki.

—— Note on *Microdiscus speciosus*.

In Am. Jour. Sci., 3d series, vol. 13, 1877, p. 141.

—— On some embryonic forms of Trilobites.

In Am. Jour. Sci., 3d series, vol. 13, 1877, p. 265, pl. 4.

Metamorphoses of *Olenellus* (*Elliptocephalus*) *asaphoides*.

—— Description of two new species of Primordial fossils.

In Am. Jour. Sci., 3d series, vol. 15, 1878, p. 124.

Solenopleura nana.

—— Note on the development of *Olenellus asaphoides*.

In Am. Jour. Sci., 3d series, vol. 15, 1878, p. 129.

—— Life of the Silurian age.

New York Tribune Extra, September 2, 1879.

In this paper Mr. S. W. Ford gives generic figures of Trilobites, including figures of *Microdiscus speciosus*.

—— Note on the Trilobite *Atops trilineatus* Emmons.

In Am. Jour. Sci., 3d series, vol. 19, 1880, p. 152.

—— On additional embryonic forms of Trilobites from the Primordial rocks of Troy, New York, with observations on

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Ford (S. W.)—Continued.

the genera *Olenellus*, *Paradoxides*, and *Hydrocephalus*.

In Am. Jour. Sci., 3d series, vol. 22, 1881, p. 250, 13, figs.

—— Note on the age of the Swedish Paradoxides beds.

In Am. Jour. Sci., 3d series, vol. 32, 1886, p. 473.

—— and **Dwight** (W. B.) Preliminary report of S. W. Ford and W. B. Dwight upon fossils obtained in 1885 from metamorphic limestones of the Taconic series of Emmons, at Canaan, New York. Pl. 7.

In Am. Jour. Sci., 3d series. vol. 31, 1886, p. 248.

Genal spine of Trilobite, perhaps *Asaphus megistos*.

Frech (Fritz). Ueber das Devon der Ostalpen.

In Zeitschr. Deutsch. geol. Gesell., Berlin, vol. 39, 1888, p. 659.

Phacops, *Cheirurus*, *Encrinurus*, *Arethusina*.

—— Die palæozoischen Bildungen von Cabrières, etc.

In Zeitschr. Deutsch. geol. Gesell., Berlin, vol. 39, 1887, p. 360, pl. 24.

Harpes, *Phacops*, *Proetus*, *Dechenella*, *Lichas*, *Cheirurus*, *Bronteus*, *Ogygia*.

Gehler (J. C.) De quibusdam varioribus agri Lipsiensis petrificatis. Spec. I. Trilobites f. *Entomoslithus paradoxus* Linné. Lipsiæ, 1793 [1 pl.].

The author gives a sketch of the bibliography of the Trilobites, and figures several specimens of *Calymene blumenbachii*.

Geinitz (H. B.) Grundriss der Versteinerungs-Kunde. Dresden, 1846, 28 pls.

Limulus Halicyne, *Belinurus*, *Eurypterus*, *Cytherina*, *Calymene*, *Homalonotus*, *Dipleura*, *Trimerus*, *Cyphaspis*, *Phacops*, *Aconia*, *Illænus*, *Archegonus*, *Asaphus*, *Dysplanus*, *Nileus*, *Ampyx*, *Trinucleus*, *Ogygia*, *Odontopleura*, *Arges*, *Bronteus*, *Paradoxides*, *Olenus*, *Conocephalus*, *Ellipsocephalus*, *Harpes*, *Cytherea*, *Cypridina*, *Cyprella*, *Cypridella*, *Pollicipes*, *Cyclus*.

—— Carbonformation und Dyas in Nebraska. Dresden, 1866, 5 pls.

Phillipsia sp.?, *Cythere*.

Genzmar. Beschreibung einer versteinerten Muschel mit dreifachen Rücken. (*)

In Gesell. der Ober-Lausitz Lobau, vol. 2, 1758; also, vol. 3, p. 185, fig. 17–21; Neues, Mag., Hamburg, 1772.

This author gives a description of the Trilobites of Mecklenburg, especially those of his own collection.

Gerstäcker (A.) In Bronn's Die Klassen und Ordnungen der Arthropoden wis-

Gerstäcker (A.)—Continued.

senschaftlich dargestellt in Wort und Bild. Crustacea. Leipzig und Heidelberg, 1866–'79, p. 1142, pls. 43–49.

Agnostus, *Homalonotus*, *Phacops*, *Dalmanites*, *Cheirurus*, *Cromus*, *Deiphon*, *Staurocephalus*, *Ampyx*, *Hydrocephalus*, *Acidaspis*, *Telephus*, *Æglina*, *Lichas*, *Sphærexochus*, *Triarthrus*, *Dindymene*, *Barrandia*, *Illænus*, *Nileus*, *Ogygia*. *Bronteus*, *Asaphus*, *Paradoxides*, *Phillipsia*, *Carmon*, *Ellipsocephalus*, *Cyphaspis*, *Arethusina*, *Proetus*, *Arionellus*, *Remopleurides*, *Bohemilla*, *Calymene*, *Conocephalites*, *Olenus*, *Peltura*, *Arera*, *Sao*, *Phacoparia*, *Amphion*, *Encrinurus*, *Zethus*. *Trinucleus*, *Dionides*. *Harpides*, *Harpes*, *Aristozoe*, *Bryrichia*, *Bolbozoe*, *Callizoe*, *Caryon*, *Crescentilla* *Cythere*, *Cytheropsis*, *Elpe*, *Entomis*, *Heppa*, *Leperditia*, *Isochilina*, *Orozoe*, *Nothozoe*, *Primitia*, *Zonozoe*, *Cryptocaris*, *Aptychopsis*, *Adelophthalmus*, *Eurypterus*, *Limulus*, *Pterygotus*, *Belinurus*, *Prestwichia*, *Hemiaspis*.

Giebel (C.) Die silurische Fauna des Unterharzes.

In Abhandl. Nat. Vereins Sachsen u. Thüringen, vol. 1, 1858, p. 1, 7 pls.

Harpes, *Proetus*, *Cyphaspis*, *Phacops*, *Lichas*, *Dalmannia*, *Acidaspis*, *Bronteus*.

Goldfuss (A.) Observation sur la place qu'occupent les Trilobites dans le règne animal.

In Annales Sci. Nat. Paris, vol. 15, 1828, p. 83, pl. 2.

Asaphus, *Calymene*.

—— Catalogue des Trilobites.

In Handbuch der Geognosie von de la Beche, 1832.

This list was copied by Dr. Jacob Green in his "Monograph of the Trilobites of North America," p. 20.

—— Beiträge zur Familie der fossilen Crustaceen.

In Nova Acta Physico Med., vol. 19, 1839, Breslau, p. 353, pl. 33.

Harpes n. g., *Arges* n. g., *Brontes* n. g., *Illænus? triacanthus*.

—— Systematische Uebersicht der Trilobiten und Beschreibung einiger neuen Arten.

In Neues Jahrbuch für Mineral., 1843, p. 537, pls. 4–6.

Harpes, *Paradoxides*, *Olenus*, *Anthes* n. g., *Olenus scarabæoides*, *Conocephalus*, *Ellipsocephalus*, *Proetus*, *Acaste*, *Gerastos* n. g., *Phacops*, *Calymene*, *Homalonotus*, *Dipleura*, *Cryptolithus*, *Ampyx*, *Asaphus*, *Isotelus*, *Symphysurus* n. g., *Ogygia*, *Cryptonymus*, *Odontopleura*, *Ceraurus*, *Otarion*, *Arges*, *Zethus*, *Amphion*, *Bronteus*, *Illænus*, *Bumastus*, *Nilcus*, *Agnostus*.

Classifies 204 species under 32 genera.

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Goodchild (J. G.) and **Postlethwaite** (J.). *See* **Postlethwaite** (J.) and **Goodchild** (J. G.).

Green (Jacob). Synopsis of the Trilobites of North America. In which some new genera and species are proposed.

Monthly Am. Jour. Geology, Phila., vol. 2, 1832, p. 558, pl. 14. Republished in Dr. Jacob Green's "Monograph of the Trilobites of North America," Phila., 1832. List given in Dr. R. Harlan's "Med. Phys. Researches," Phila., 1835, p. 300.

Calymene blumenbachii, C. callicephala, C. selenecephala, C. platys, C. microps, C. anchiops, C. diops, C. bufo, Asaphus caudatus, A. selenurus, A. pleuroptyx, A. wetherilli, A. micrurus, A. limulurus, A. laticostatus, Trimerus n. g., *T. delphinocephalus* (pl. 14, fig. 1), *Cryptolithus* n. g., *C. tessellatus* (pl. 14, fig. 4), *Dipleura* n. g., *D. dekayi* (pl. 14, figs. 8, 9), *Isotelus gigas, I planus, I. cyclops* (pl. 14, fig. 7), *Triarthrus* n. g., *T. beckii* (pl. 14, fig. 6), *Paradoxides boltonii* (pl. 14, fig. 5), *Ceraurus* n. g., *C. pleurexanthemus* (pl. 14, fig. 10).

—— A monograph of the Trilobites of North America, with colored models of the species. Philadelphia, 1832, 94 pp., 1 pl. (Oct. 1, 1832).

Calymene, Asaphus, Hemicrupturus n. g., *Ogygia, Isotelus, Cryptolithus, Dipleura, Trimerus, Ceraurus, Triarthrus, Nuttainia, Brongniartia.*

—— A supplement to the monograph of the Trilobites of North America, with colored models of the species. Philadelphia, 1835, 24 pp. (May 1, 1835).

Paradoxides, Calymene, Asaphus.

—— A new Trilobite. Letter to the editor, Dec. 26, 1832.

In Am. Jour. Sci., 1st series, vol. 23, 1833, p. 397.

Asaphus myrmecoïdes.

—— Description of a new Trilobite from Nova Scotia.

In Trans. Geol. Soc. Pennsylvania, vol. 1, pt. 1, 1834, p. 37, pl. 4.

Asaphus crypturus.

—— Description of some new North American Trilobites.

In Am. Jour. Sci., 1st series, vol. 25, 1834, p. 334.

Calymene odontocephalus, Asaphus astragalotes, A. tetragonocephalus, Paradoxides harlani.

—— Description of a new Trilobite.

In Am. Jour. Sci., 1st series, vol. 32, 1837, p. 167.

Calymene phtyctainodes, Asaphus platypleurus.

—— Description of two new species of Trilobites. Read Jan. 24, 1837.

Green (Jacob)—Continued.

In Jour. Acad. Nat. Sci. Phila., vol. 7, 1837, p. 217, 2 wood-cuts.

Cryphœus n. g., *C. boothi, Asaphus trimblii.*

J. W. Salter (Mon. Brit. Tril., p. 15) gives the following diagnosis of the genus, and uses it as a subgenus to *Phacops:* "Form of moderate size, depressed. Glabella depressed, not much expanded in front; all the lobes distinct, the front ones not greatly enlarged, genal angles long-spined. Pleura truncate, and the hinder ones often produced into spines. Tail large, of many segments; the margin spinose."

—— Description of several new Trilobites.

In Am. Jour. Sci., 1st series, vol. 32, 1837, p. 343, 2 wood-cuts.

Cryphœus, C. boothi, C. collitelus, Trimerus jacksonii, Asaphus trimblii.

—— Some remarks on the genus *Paradoxides* Brong., and the necessity of preserving the genus *Triarthrus*, proposed in the Monograph of the Trilobites of North America.

In Am. Jour. Sci., 1st series, vol. 33, 1838, p. 341.

—— Description of a new Trilobite.

In Am. Jour. Sci., 1st series, vol. 33, 1838, p. 406.

Calymene rowii.

This Trilobite was figured by Mr. Row in the Poughkeepsie Telegraph, Nov. 22, 1837.

—— Description of a new Trilobite.

In Annals Mag. Nat. History, 1st series, vol. 1, 1838, p. 79.

Calymene rowii.

—— The inferior surface of the Trilobite discovered.

In The Friend, a weekly Journal, Philadelphia, March 16, 1839.

Calymene bufo.

—— The inferior surface of the Trilobite discovered. Illustrated, with colored models. Philadelphia, 1839.

Calymene bufo.

—— Remarks on the Trilobites.

In Am. Jour. Sci., 1st series, vol. 37, 1839, p. 25.

This article appears to be a republication of the two preceding references, with the addition of the remarks on p. 38 of the Journal

—— An additional fact, illustrating the inferior surface of *Calymene bufo.*

In Am. Jour. Sci., 1st series, vol. 38, 1840, p. 410.

Grewingk (C.) Geologie von Liv- und Kurland.

In Archiv Natur. Liv-, Ehst- u. Kurl., Dorpat, vol. 2, pt. 3, 1861, p. 571, 4 pls.

Beyrichia.

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Griffith (Richard).

Two important works on the paleontology and geology of Ireland were prepared under the direction of Mr. Richard Griffith by Frederick McCoy, who will be counted as the author, although Mr. Richard Griffith was the collector of the specimens and the financial supporter of the publications.

The contributions on the Paleozoic Crustacea are given under McCoy (Frederick) in this work.

Grote (A. R.) and **Pitt** (W. H.) New specimen from the Water Lime group at Buffalo, N. Y.

In Proc. Am. Assoc. Adv. Sci., 26th meeting, Nashville, 1877, p. 300.

Pterygotus cummingsi.

—— —— Description of a new Crustacean from the Water Lime group at Buffalo.

In Bull. Buffalo Soc. Nat. Sci., vol. 3, 1875, p. 1.

Eusarcus n. g.

—— —— On new species of *Eusarcus* and *Pterygotus* from the Water Lime group at Buffalo.

In Bull. Buffalo Soc. Nat. Sci., vol. 3, 1875, p. 17, plate.

Eusarcus, Pterygotus.

Gruenwaldt (M.) Beiträge zur Kenntniss der sedimentären Gebirgsformationen des Ural.

In Mém. Acad. Sci. St.-Pétersbourg, 7th series, vol. 2, No. 7, 1860, 6 pls.

Phillipsia, Leperditia.

Guettard (E.-T.) Mémoire sur les ardoisières d'Angers.

In Mém. Acad. Sci. Paris, 1757, p. 52, pls. 7–9. Reprint: Amsterdam, 1768.

The author in his memoir on the geology of Angers gives descriptions and figures of several Trilobites. These were afterwards described by Alex. Brongniart under the genus *Ogygia* and named by this author *Ogygie* de *Guettard* and *O. desmarestii.*

Haldeman (S. S.) On the supposed identity of *Atops trilineatus* with *Triarthrus beckii.*

In Am. Jour. Sci., 2d series, vol. 5, 1848, p. 107.

Hall (Charles E.) Contribution to palæontogy from the Museum of the Second Geological Survey of Pennsylvania.

In Proc. Am. Philos. Soc., Phila., vol. 16, 1877, p. 621.

Eurypterus.

Hall (James). Description of two species of Trilobites belonging to the genus *Paradoxides.*

Hall (James)—Continued.

In Am. Jour. Sci., 1st series, vol. 33, 1838, p. 139, 2 figs.

Read before the Yale Natural History Society, March 21, 1837.

Paradoxides beckii, P. eatoni.

—— Trilobites of the inferior strata.

(Extracted and published in advance of the "Palæontology of New York," vol. 1, Albany, 1846, p. 225, pls. 60–67.)

Olenus, Phacops, Calymene, Platynotus, Trinucleus, Asaphus Isotelus, Acidaspis, Ceraurus, Illænus, Agnostus.

—— Palæontology of New York. Vol. 1. Containing descriptions of the organic remains of the lower divisions of the New York system. Albany, 1847, 100 pls.

Olenus, Phacops, Calymene, Platynotus, Trinucleus, Asaphus, Isotelus, Acidaspis, Ceraurus, Illænus, Agnostus.

—— Remarks on the observations of S. S. Haldeman "On the supposed identity of *Atops trilineatus* with *Triarthrus beckii.*"

In Am. Jour. Sci., 2d series, vol. 5, 1848, p. 322, 10 wood-cuts.

—— Descriptions of new species of fossils, and observations upon some others previously not well known, from the Trenton limestones.

In Third Rept. New York State Cab. Nat. Hist., 1850, p. 167, 5 pls. (2 eds.).

Asaphus extans.

This species was used by Mr. E. Billings for the type of *Bathyurus.*

—— Description of new or rare species of fossils from the Palæozoic series.

In Rept. Geol. Lake Superior Land Dist. (Foster and Whitney), 1851, pt. 2, p. 203, pls. 22–35.

Harpes escanabiæ, Dikelocephalus, Proetus, Phacops anchiops, P. callicephalus, Asaphus barrandi; tracks of a Crustacean?

—— Palæontology of New York. Vol. 2. Containing descriptions of the organic remains of the lower divisions of the New York system. Albany, 1852, 104 pls.

Phacops, Proetus, Calymene, Homalonotus, Arges, Lichas, Acidaspis, Ceraurus, Cybele, Bumastis, Beyrichia, Cytherina, Onchus.

—— Notes on some fossils of the so-called Taconic system described by Doctor Emmons.

In Am. Jour. Sci., 2d series, vol. 19, 1855, p. 434.

Olenus (Ellipsocephalus) asaphoides.

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Hall (James)—Continued.

—— Description of new species of fossils from the Carboniferous limestone of Indiana and Illinois.

Read in 1856 and published separately by the author. See, also, Trans. Albany Inst., vol. 1, pt. 1, 1857, p. 1.

Cytherina carbonaria.

Descriptions of these fossils, with additional notes by R. P. Whitfield, were published in the Bull. Am. Mus. Nat. Hist., New York, vol. 1, No. 3, 1882.

The original descriptions, with additional observation by James Hall, with the plates from R. P. Whitfield's memoir, were published in the 12th Annual Rept. Geol. Nat. Hist. Indiana, 1882, pp. 321-375, pls. 29-32.

—— The Trilobites of the shales of the Hudson River group.

In Twelfth Rept. New York State Cab. Nat. Hist., 1859, p. 59, 3 wood-cuts. See, also, Palæont. New York, vol. 3, 1859; Geol. Vermont, vol. 1, 1861; 13th Rept. New York State Cab. Nat. Hist., 1860.

Olenus thompsoni, O. vermontana, Peltura (Olenus) holopyge.

—— Geological Survey New York. Palæontology. Vol. 3. Containing descriptions and figures of the organic remains of the Lower Helderberg group and the Oriskany sandstone. 1855-'59.

Pt. 1, text, 1859; pt. 2, plates, 1861, 120 pls.

Proetus, Phacops, Dalmania, Homalonotus, Lichas, Acidaspis, Bronteus, Eurypterus, Dolichopterus n. subgenus, *Pterygotus, Leperditia, Beyrichia, Ceratiocaris, Olenus thompsoni, O. vermontana, Peltura (Olenus) holopyge.*

—— Description of new species of fossils from the Silurian rocks of Nova Scotia.

In Canadian Naturalist, vol. 5, 1860, p. 144.

Homalonotus dawsoni Hall, *Calymene blumenbachii, Dalmania logani* Hall, *Beyrichia pustulosa* Hall, *B. æqilatera* Hall, *Leperditia sinuata* Hall.

—— Contributions to palæontology, 1858 and 1859. Notes and observations upon the fossils of the Goniatite limestone in the Marcellus shale of the Hamilton group in the eastern and central parts of the State of New York, and those of the Goniatite beds of Rockford, Indiana; with some analogous forms from the Hamilton group proper.

In Thirteenth Rept. New York State Cab. Nat. Hist., 1860, p. 95.

Proetus doris Hall.

—— Note upon the Trilobites of the shales of the Quebec group in the town of Georgia, Vermont.

In Thirteenth Rept. New York State Cab. Nat. Hist., 1860, p. 113.

Barrandia n. g.

This term was used by Frederick McCoy, in 1844, for a genus of Trilobites.

Bathynotus n. g.

—— New species of fossils from the Hudson River group of Ohio and the Western States.

In Thirteenth Rept. New York State Cab. Nat. Hist., 1860, p. 119.

Calymene christyi, Proetus parviusculus.

—— Geological Survey of Wisconsin. Description of new species of fossils from the investigations of the survey, etc. Report of the superintendent of the Geological Survey, exhibiting the progress of the work, January 1, 1861, p. 11.

Dalmanites, Calymene, Illænus.

—— Preliminary notice of the Trilobites and other Crustacea of the Upper Helderberg, Hamilton, and Chemung groups.

Author's edition, published in 1861, 11 pls., 170 pp.; 15th Rept. New York State Cab. Nat. Hist., 1862, p. 82.

Olenellus n. g., *Proetus, Phacops, Dalmania, Calymene, Homalonotus, Lichas, Acidaspis, Beyrichia, Leperditia.*

—— Note on the genus Cypricardites.

In Fifteenth Rept. New York State Cab. Nat. Hist., 1861, p. 192. Plate illustrating certain genera and species described by T. A. Conrad in the 5th Annual Rept. Pal. Dept. New York Geol. Survey, 1841, pl. 11 (reprint).

Dicranurus, pl. 11, fig. 1; *Aspidolites*, pl. 11, fig. 2; *Acidaspis tuberculatus*, pl. 11, fig. 3.

—— Note upon the Trilobites of the Hudson River group, in the town of Georgia, Vermont.

In Geol. Vermont, vol. 1, 1861, p. 367, pl. 13.

Barrandia, B. vermontana, Bathynotus, B. holopyga.

—— Palæontology of Wisconsin. Remarks upon the condition of the fossils in the rocks of the several formations. Catalogue of fossils known in the Palæozoic formations of Wisconsin, with observations upon some of the known species and descriptions of several new forms.

Geol. Survey Wisconsin, vol. 1, 1862, p. 425.

—— On a new Crustacean from the Potsdam sandstone. A letter addressed to Principal Dawson, dated Albany, Oct. 31, 1862.

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Hall (James)—Continued.

In Canadian Naturalist, vol. 7, 1862, p. 443, figure. See The Geologist, vol. 6, London, 1863, p. 247, figure.

Aglaspis n. g.

—— On the occurrence of Crustacean remains of the genera *Ceratiocaris* and *Dithyrocaris*, with a notice of some new species from the Hamilton group and Genesee slate.

In Sixteenth Rept. New York State Cab. Nat. Hist., Albany, 1863, p. 71, plate.

—— Preliminary notice of the fauna of the Potsdam sandstone, with remarks upon the previously known species of fossils, and description of some new ones from the sandstones of the Upper Mississippi Valley.

In Sixteenth Rept. New York State Cab. Nat. Hist., 1863, p. 119, 6 pls. Supplementary note, p. 110.

Dikelocephalus, *Triarthrella* n. g., *Conocephalus*, *Arionellus*, *Chariocephalus* n. g., *Ptychaspis* n. g., *Lichas*, *Illænurus* n. g., *Amphion?*, *Agnostus*, *Pemphigaspis* n. g., *Aglaspis*.

—— Notice of some new species of fossils from a locality of the Niagara group in Indiana, with a list of identified species from the same place.

In Trans. Albany Inst., vol. 4, 1864, p. 195. Author's edition published May 2, 1863, pp. 1–34.

Dalmania, *Cyphaspis*, *Lichas*.

Plates of the species. 28th Rept. New York State Mus. Nat Hist., 1879.

—— Account of some new or little known species of fossils from rocks of the age of the Niagara group.

In Twentieth Rept. New York State Cab. Nat. Hist., 1867, p. 305, 21 pls. Originally printed in advance for the 18th Report New York State Cab. Nat. Hist., 1864. Revised edition, Albany, 1870, with 22 pls.

Dalmania, *Calymene*, *Lichas*, *Acidaspis*, *Ceraurus*, *Sphærexochus*, *Illænus*, *Encrinurus*, *Bronteus*.

—— Geological Survey of the State of Wisconsin, 1859–'63. Palæontology. Pt. 3. Organic remains of the Niagara group and the associated limestones. 94 pp., 18 pls. Albany, 1871.

The same was published in 1864 in advance for the 18th Rept. New York State Cab. Nat. Hist., 1867, under the title of "Account of some new or little known species of fossils from rocks of the age of the Niagara group." See 20th Rept. New York State Cab. Nat. Hist., rev. edition, 1870, p. 347.

Hall (James)—Continued.

—— Descriptions of new species of fossils from the Hudson River group in the vicinity of Cincinnati, Ohio.

In Twenty-fourth Rept. New York State Mus. Nat. Hist., Albany, 1872, p. 225, 1 pl.

Published Oct., 1871, in advance of the State Cab. report.

Leperditia, *Beyrichia*.

—— Descriptions of new species of Crinoids and other fossils from strata of the age of the Hudson River group and Trenton limestone.

In Twenty-fourth Rept. New York State Mus. Nat. Hist., 1872, p. 205, 3 pls.

Dalmania breviceps, *Proetus parvisculus*.

Advance sheets of this article were printed and distributed in November, 1866, except the first four species of Crinoidea mentioned in the foot-note on p. 205, which were first published in 1871 in a pamphlet entitled "New species of fossils from the Hudson River group in the vicinity of Cincinnati, Ohio."

—— The fauna of the Niagara group in central Indiana.

Documents only of Twenty-eighth Rept. New York State Mus. Nat. Hist., 1876, 34 pls.

—— The fauna of the Niagara in central Indiana.

In Twenty-eighth Rept. New York State Mus. Nat. Hist., 1879, p. 99, 34 pls.

Cyphaspis, *Dalmanites*, *Odontocephalus*, *Calymene*, *Homalonotus*, *Lichas*, *Ceraurus*, *Illænus*, *Beyrichia*, *Leperditia*.

—— Illustrations of Devonian fossils: Gasteropoda, Pteropoda, Cephalopoda, Crustacea, and Corals of the Upper Helderberg, Hamilton, and Chemung groups, etc. Albany, 1876, 7 pp., 133 pls.

Proetus, *Phillipsia* (*Brachymetopus?*), *Phacops*, *Dalmanites*, *Calymene*, *Homalonotus*, *Lichas*, *Acidaspis* (*Teratаspis*), *Dithyrocaris*, *Ceratiocaris*.

—— Descriptions of new species of fossils from the Niagara formation at Waldron, Indiana.

In Trans. Albany Inst., vol. 10, 1883, p. 57. Read 1879, and published separately in 1881.

Acidaspis fimbriata, *Illænus* (*Bumastus*), *Ioxus*.

—— Description of the species of fossils found in the Niagara group at Waldron, Indiana.

In Eleventh Ann. Rept. for 1881, Dept. Geol. Nat. Hist. Survey Indiana, 1882, p. 217, 36 pls.

Cyphaspis, *Dalmanites*, *Odontocephalus*, *Calymene*, *Homalonotus*, *Lichas*, *Acidaspis*, *Illænus*, *Beyrichia*, *Leperditia*.

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Hall (James)—Continued.

—— Note on the *Eurypteridæ* of the Devonian and Carboniferous formations of Pennsylvania, with a supplementary note on the *Stylonurus excelsior*.

In Proc. Am. Assoc. Adv. Sci., 33d meeting, Phila., 1884, p. 420.

—— *Eurypteridæ* from the Devonian and Carboniferous formations of Pennsylvania. With 6 pls.

Extracted Rept. Prog. PPP., 2d Geol. Survey Pennsylvania, 1884.

—— Note on the *Eurypteridæ* of the Devonian and Carboniferous formations of Pennsylvania.

In Second Geol. Survey Pennsylvania, Rept. Prog. PPP., 1884, 6 pls.

Eurypterus, Dolichopterus, Pterygotus, Stylonurus, Eurypterus (Anthraconectes) mazonensis M. & W.

—— Description of a new species of *Stylonurus* from the Catskill group.

In Thirty-sixth Rept. New York State Mus. Nat. Hist., 1884, p. 76, pl. 5.

Stylonurus excelsior Hall.

There was a short notice of this species published by D. S. Martin (Trans. New York Acad. Sci., vol. 2, 1882, p. 8). This notice was based upon a cast of the carapace in the New York State Museum, which had been labeled with name and locality by Prof. James Hall.

—— and **Whitfield** (R. P.) Descriptions of new species of fossils from the vicinity of Louisville, Ky., and the Falls of the Ohio.

In Twenty-fourth Rept. New York State Mus. Nat. Hist., 1872, p. 181, pl. 13, figs 20 and 21.

Illænus cornigerus H. & W.

—— —— Geological Survey of Ohio. Vol. 2. Geology and palæontology. Pt. 2. Palæontology. 1875, p. 67, pls. 1–12.

Proetus, Dalmania, Calymene, Lichas, Encrinurus, Leperditia (Isochilina), Beyrichia, Plumulites.

—— —— Palæontology.

In U. S. Geol. Expl. 40th Parallel, vol. 4, pt. 2, 1877, 7 pls.

Dikellocephalus, Conocephalites, Crepicephalus (Loganellus), Ptychaspis, Chariocephalus, Bathyurus, Proetus, Ogygia, Agnostus.

—— and **Clarke** (John M.) Geological Survey of the State of New York. Palæontology. Vol. VII. Text and plates, containing descriptions of the Trilobites and other Crustacea of the Oriskany, Upper Helderberg, Hamilton, Portage, Chemung, and Catskill groups. Albany, 1888, 236 pp., 36 pls.

Hall (James) and **Clarke** (John M.)—Continued.

Trilobita: *Calymene, Homalonotus, Bronteus, Phacops, Dalmanites* subgen., *Hausmanni* n. s. g., *Coronura* n. s. g., *Cryphæus, Odontocephalus, Corycephalus, Chasmops, Lichas* subgen., *Terataspis, Conolichas, Hoplochas, Arges, Ceratolichas, Proetus, Phœthonides, Cyphaspis.*

Xiphosura: *Protolemulus, Eurypterus, Stylonurus.*

Phyllocaridæ: *Ceratiocaris, Echinocaris, Elymocaris, Tropidocaris.*

Pinæcaridæ: *Mesothyra* n. g.

Rhinocaridæ: *Rhinocaris* n. g.

Discinocaridæ: *Spathiocaris, Dipterocaris.*

Decapoda: *Palæopalæmon.*

Phyllopoda: *Estheria, Schizodiscus* n. g.

Cirripidæ: *Protobalanus.*

Palæocrenusia: *Stropbilepis* n. g., *Turrilepas.*

Hancock (Abbany). Remarks on certain vermiform fossils found in the mountain limestone districts of the north of England.

In Rept. 28th Meeting Brit. Assoc. Adv. Sci., 1858, Tran. of Sec., p. 80.

Tracks of Trilobites.

Harlan (Richard). Critical notices of various organic remains hitherto discovered in North America.

In Trans. Geol. Soc. Pennsylvania, vol. 1, pt. 1, 1834, p. 46, 1 pl.

The author herein describes two species of *Eurypterus* and gives a list of North American Trilobites.

Eurypterus remipes De Kay, *E. lacustris* Harlan.

—— Notice of nondescript Trilobites from the State of New York, with observations on the genus *Triarthrus*, etc.

In Trans. Geol. Soc. Pennsylvania, vol 1, pt. 2, 1835, p. 263, pl. 15.

Paradoxides triarthrus Har., *P. arcuatus* Har., *P. scaraboides* Brong.

—— Medical and physical researches, or original memoirs in medicine, surgery, physiology, geology, zoology, etc. Phila., 1835, 36 pls.

Contains a republication of the above articles under Harlan, pp. 253–313 and 400–403.

Hartt (C. F.) Fossils of the Primordial or Acadian group at St. John.

In Acadian Geology, the geological structure, organic remains, and mineral resources of Nova Scotia, etc., by J. W. Dawson, 2d ed., London, 1868, pp. 641–657; also 3d ed., 1878, with supplement (wood-cuts).

Paradoxides, Conocephalites, Microdiscus, Agnostus.

Mr. C. F. Hartt, in his original description of *Microdiscus dawsoni* Hartt, described the species under the new generic name of *Dawsonia*.

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Hartt (C. F.)—Continued.

In the Acadian Geology the species is placed under the genus *Microdiscus* on the authority of Mr. E. Billings, of the Canadian Geological Survey.

—— Appendix B. List of New Brunswick fossils.

See Bailey's "Observations on the Geol. of Southern New Brunswick, etc.," 1865, p. 143.

—— and **Rathbun** (Richard). Morgan Expedition, 1870–'71. On the Devonian Trilobites and Mollusks of Ereré, Province of Pará, Brazil.

In Annals Lyceum Nat. Hist., New York, vol. 11, 1875, p. 110.

Dalmania paituna H. & R., *Homalonotus oiara* H. & R.

Hauer (F. von). Ueber Barrande's Versuch einer Classifikation der Trilobiten.

In Sitzungsber. d. Wien. Akad. Math.-naturw, Classe, V, p. 304, 1850.

Haulp (K.) Die Fauna der Graptholitengest.

In Lausitzische Mag., vol. 44, Görlitz, 1878, p. 75, pl. 5.

Beyrichia.

Hawle (Ignaz). See **Corda** (A. J. C.) and **Hawle** (Ignaz).

Hayden (F. V.) See **Meek** (F. B.) and **Hayden** (F. V.).

Heidenhain (F.) Ueber Graptholitenführende Diluvial-Geschiebe der norddeutschen Ebene.

In Zeitschr. Deutsch. geol. Gesell., vol. 21, 1869, p. 143, plate.

Calymene blumenbachi, Dalmanites caudata, Odontopleura ovata, O. nutica, Cyphaspis, Homalonotus, Beyrichia klœden, B. maccoyana, B. tuberculatus.

Hellman (A.) Die Petrefacten Thüringens. Cassel, 1866, 5 pts., 24 pls.

Dalmania tuberculata, Acidaspis buchi, Paradoxides spinosus.

Hermann (L. D.) Maslographia Brigæ, Massel, 1711, pl. 9, fig. 50; pl. 11, fig. 44; pl. 12, fig. 31.

The author herein compares a fragment of the pygidium of an *Encrinurus* to a scollop shell.

Herrick (C. L.) A sketch of the geological history of Licking County, accompanying an illustrated catalogue of Carboniferous fossils from Flint Ridge, Ohio.

In Bull. Denison Univ., vol. 2, pt. 1, 1887, p. 5, 7 pls.

Proetus, Phillipsia, Griffithides, Brachymetopus, Dalmanites?.

Herrick (C. L.)—Continued.

—— Appendix 2. A Waverly Trilobite.

In Bull. Denison Univ., vol. 2, pt. 1, 1887, p. 69, pl. 7, fig. 14.

Phillipsia shumardi Herrick.

—— The geology of Licking County, Ohio. Pt. IV. The Subcarboniferous and Waverly groups.

In Bull. Denison Univ., vol. 3, 1888, p. 13, pls. 2, 11, and 12.

Phillipsia meramecensis Sh., *P. shumardi* Her., *P. præcursor* Her.

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—— On some undescribed fossils from the Menevian group, with a note on the Entomostraca by Prof. T. Rupert Jones.

In Quart. Jour. Geol. Soc. London, vol. 28, 1872, p. 173, pls. 5–7.

Anoplenus, Cerausia n. g., *Erinnys, Conocoryphe, Arionellus, Holocephalina, Agnostus, Leperditia, Entomis.*

—— On the Tremadoc rocks in the neighborhood of St. David's, South Wales, and their fossil contents.

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Nesseretus n. g., *Niobe.*

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Hicks (Henry)—Continued.

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—— Appendix to Fossiliferous Cambrian shales, near Cærnarvon, by J. E. Marr.

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—— Tableau des pétrifications de la Suède distribuées en ordre systématique. Stockholm, 1829.

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Holl (F.) Handbuch der Petrefactenkunde, etc. Dresden, 1841, p. 155.

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The author gives short descriptions of the Trilobites described by Alex. Brongniart, J. W. Dalman, E. Eichwald, von Schlotheim, and others.

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Holm (Gerhard). Anteckningar om Wahlenberg's *Illænus crassicauda.*

In Svenska Vetensk. Akad. Förhandl., 1880, No. 4, p. 3, Stockholm, pl. 5.

—— Bemerkungen über *Illænus crassicauda* Wahl.

In Zeitschr. deutsch. geol. Gesell., vol. 32, pt. 2–4, 1880, p. 559, pl. 23.

—— Ueber einige Trilobiten aus dem Phyllograptus-Schiefer Dalekarliens.

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Pliomera törnquisti, Megalaspis dalecarlicus, Ampyx pater, Agnostus törnquisti, Trilobites brevifrons.

—— De Svenska arterna af Trilobitolag tet *Illænus* Dalman.

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Holm (Gerhard)—Continued.

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—— Om förekomsten af en Cruziana i öfversta Olenidskiffern vid Knifvinge i Vreta Kloster Socken i Östergötland.

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In Canadian Naturalist, vol. 5, 1860, p. 293.

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In Quart. Jour. Geol. Soc. London, vol. 26, 1870, p. 490.

The note by Prof. T. R. Jones, on p. 492, on some Entomostraca from Arisaig, mentions the following genera:

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—— Notes of examination by Prof. James Hall of the Silurian collection of the Provincial Museum, by the Rev. D. Honeyman.

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Asaphus ditmarsiæ Honeyman.

—— The Giant Trilobite of Moose River Iron Mine, Nova Scotia.

In Proc. and Trans. Nova Scotian Inst. Nat. Sci., vol. 7, pt. 1, 1888, p. 63.

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—— Supplement to Catalogue of Lower Silurian fossils of the Cincinnati group, etc. Cincinnati, July 10, 1879.

—— Descriptions of new species of fossils from the Cincinnati group, Ohio and Kentucky.

In The Palæontologist, Cincinnati, No. 7, April 16, 1883.

Tracks of Crustacean (?), pl. 2, fig. 4.

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Jones (T. Rupert). On Permian Entomostraca.

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Cythere.

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Jones (T. Rupert)—Continued.

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Beyrichia.

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Beyrichia.

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Beyrichia.

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Leperditia.

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—— Additional notes on Palæozoic Entomostraca from Canada.

In Annals Mag. Nat. Hist., 3d series, London, vol. 1, 1858, p. 340.

Leperditia, Isochilina.

—— On the Palæozoic Entomostraca of Canada.

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Beyrichia, Leperditia, Isochilinia n. g., *Cytheropsis.*

—— Explanation map 32. The geology of the neighborhood of Edinburgh, by H. H. Howell and A. Geikie; with appendix and list of fossils, by J. W. Salter.

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Jones (T. Rupert)—Continued.

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—— A monograph of the fossil *Estheriæ.*

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Estheria, Leaia n. g., *Beyrichia, Candona, Cypridea.*

—— Note on *Estheria niddendorfii.*

In Quart. Jour. Geol. Soc. London, vol. 19, 1863, p. 73.

—— On fossil *Estheria* and their distribution.

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—— and **Kirkby** (J. W.) Notes on the Palæozoic bivalved Entomostraca. No. 5.

In Annals Mag. Nat. Hist., 3d series, London, vol. 15, 1865, pl. 20, p. 404.

Leperditia, Cytherella, Bairdia, Cythere.

—— and **Holl** (H. B.) Notes on the Palæozoic bivalved Entomostraca. No. 6.

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Primitia n. g.

—— and **Kirkby** (J. W.) Notes on Palæozoic bivalved Entomostraca. No. 7.

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Entomoconchus, Daphnia, Bairdia, Cythere.

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In Annals Mag. Nat. Hist., 4th series, London, vol. 2, 1868, p. 54, pl. 7.

Primitia, Cythere, Bairdia.

—— and **Holl** (H. B.) Notes on Palæozoic bivalved Entomostraca. No. 9.

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Cythere, Bairdia, Beyrichia, Primitia, Thlipsura n. g., p. 213; *Cytherellina* n. g., p. 215; *Kirkbya* n. g., *Movea* n. g., *Æchmina* n. g., p. 217.

—— On ancient Water-fleas of the Ostracodous and Phyllopodous tribes (bivalved Entomostraca).

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Leperditia, Bairdia, Thlipsura, Cythere, Cytherella, Cytherellina, Æchmina, Carbonia, Cypridina, Cypridella, Cyprella, Entomoconchus, Entomis, Primitia, Kirkbya, Moorea, Isochilinia, Beyrichia, Leaia, Estheria.

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Jones (T. Rupert)—Continued.

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Cytheroid Entomostraca.

—— On the Palæozoic bivalved Entomostraca.
In Proc. Geologist Assoc., 1870.

—— Note on the Entomostraca from the Cambrian rocks of St. David's.
In Quart. Jour. Geol. Soc. London, vol. 28, 1872, p. 183, pl. 5.
Leperditia, *Entomis*. Larval trilobite?
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—— Notes on the Palæozoic bivalved Entomostraca. No. 10.
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Entomis, *Entomidella* n. g.

—— On some bivalved Entomostraca, chiefly Cypridenidæ of the Carboniferous formations.
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Sulcuna n. g., *Cyprella*.

—— Ancient Water-fleas, etc. Pt. 2.
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Cythere, *Thlipsura*.

—— Notes on some forms of British Entomostraca from the Silurian rocks of Peeblesshire.
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Beyrichia, *Bairdia*, *Entomis*.

——, **Kirkby** (J. W.) and **Brady** (M. P.) Monograph of British fossil bivalve Entomostraca from the Carboniferous formations.
In Palæont. Soc. London, 1874.
Pt. 1. The Cypridinadæ and their allies, 5 pls
Cypridina, *Asterope*, *Philomedes*, *Bradycinetus*, *Eurypylus*, *Conchœcia*, *Halocyris*, *Heterodesmus*, *Polycope*, *Cytherella*, *Cypridinella* n. g., *Cypridellina* n. g., *Cypridella*, *Sulcuna*, *Cyprella*, *Rhombina* n. g., *Entomoconchus*, *Ofa* n. g., *Chadocopa*, *Platycopa*.

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In Annals Mag. Nat. Hist., 4th series, London, vol. 15, 1875, p. 52, pl. 6.
Beyrichia, *Leperditia*, *Primitia*, *Bairdia*, *Cythere*, *Cytherella*.

—— Notes on some fossil bivalved Entomostraca.
In Geol. Mag., decade 2, vol. 5, 1878, p. 100, pl. 3.
Esthere, *Cypris*, *Candona*, *Cypridia*.

Jones (T. Rupert) and **Kirkby** (J. W.) Description of the species of the Ostracodous genus *Bairdia* McCoy, from the Carboniferous strata of Great Britain.
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In Annals Mag. Nat. Hist., 5th series, London, vol. 4, 1879, p. 28, pls. 2 and 3.
Carbonia n. g.

—— Notes on the Palæozoic Entomostraca. No. 13. *Entomis serrato-striata* and others of the so-called Cypridinen of the Devonian schist of Germany.
In Annals Mag. Nat. Hist., 5th series, London, 79, p. 182, pl. 11.

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—— Notes on some Palæozoic Entomostraca. No. 14. Some Cambrian and Silurian *Leperditia* and *Primitia*.
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In Annals Mag. Nat. Hist., 5th series, London, vol. 9, 1882, p. 168.

—— Notes on some Palæozoic bivalved Entomostraca. No. 15.
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Primitia.

—— Notes on the Palæozoic bivalved Entomostraca. No. 16. 1. Some Palæozoic and other bivalved Entomostraca from Siberian Russia, pl. 6. 2. Some Palæozoic bivalved Entomostraca from Spitzbergen, pl. 9.
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Entomis, *Leperditia*, *Estheria*, *Primitia*.

—— Notes on the late Mr. Tate's specimens of the Lower Carboniferous Entomostraca from Berwickshire, Northumberland.
In Proc. Berw. Nat. Club, vol. 10, 1884, 1 pl.
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Jones (T. Rupert)—Continued.

—— Notes on the Palæozoic bivalved Entomostraca. No. 17. Some North American *Leperditia* and allied forms.

In Annals Mag. Nat. Hist., 5th series, London, vol. 14, 1884, p. 339.

Leperditia, Isochilina, Primitia.

—— Report of the committee, consisting of Mr. R. Etheridge, Dr. H. Woodward, and Prof. T. Rupert Jones (secretary), on the fossil *Phyllopoda* of the Palæozoic rocks.

In Rept. 53d Meeting Brit. Asso. Adv. Sci., 1883, p. 215.

Hymenocaris, Caryocaris, Linguloocaris.

—— Second report of the committee consisting of Mr. R. Etheridge, Dr. H. Woodward, and Prof. T. Rupert Jones (secretary), on the fossil *Phyllopoda* of the Palæozoic rocks.

In Rept. 54th Meeting Brit. Assoc. Adv. Sci., 1884, p. 75; Geol. Mag., n. s., decade 2, vol. 10, 1883, p. 461.

—— and **Kirkby** (J. W.) On some Carboniferous Entomostraca from Nova Scotia.

In Geol. Mag., n. s., decade 3, vol. 1, 1884, p. 356, pl. 12.

Leperditia, Beyrichia, Carbonia, Candona?, Cythere, Estheria, Leaia, Primitia or *Beyrichia.*

—— and **Woodward** (Henry). On some Palæozoic Phyllopoda.

In Geol. Mag., n. s., decade 3, vol. 1, 1884, p. 348.

Discinocaris, Spathiocaris, Pholadocaris, Lisgocaris, Ellipsocaris, Cardiocaris, Dipterocaris, Pterocaris, Crescentilla, Aptychopsis, Peltocaris, Pinnocaris.

—— Notes on the Palæozoic bivalved Entomostraca. No. 18. Some species of the Entomididæ.

In Annals Mag. Nat. Hist., 5th series, London, vol. 14, 1884, p. 391, pl. 15.

Entomis, Bolbozoe, Entomidella.

—— and **Woodward** (Henry). Notes on the British species of Ceratiocaris.

In Geol. Mag., n. s., decade 3, vol. 2, 1885, p. 385, pl. 10. Continued, ibid., p. 460.

—— **Kirkby** (J. W.) Notes on Palæozoic bivalved Entomostraca. No. 19. On some Carboniferous species of the Ostracodous genus *Kirkbya.*

In Annals Mag. Nat. Hist., 5th series, London, vol. 15, 1885, p. 174, pl. 3.

—— and **Holl** (H. B.) Notes on the Palæozoic bivalved Entomostraca. No. 20. On the genus *Beyrichia* and some new species.

Jones (T. Rupert) and **Holl** (H. B.)—Continued.

In Annals Mag. Nat. Hist., 5th series, London, vol. 17, 1886, p. 337, pl. 12.

Beyrichia, Bollia n. g., *Klædenia* n. g.

—— —— Notes on the Palæozoic bivalved Entomostraca. No. 21. On some Silurian genera and species.

In Annals Mag. Nat. Hist., 5th series, London, vol. 17, 1886, p. 403, pls. 13, 14.

Strepula n. g., *Bollia, Placentula* n. g., *Primitia.*

—— and **Kirkby** (J. W.) Notes on the distribution of the Ostracoda of the Carboniferous formation of the British Isles.

In Abstracts Proc. Geol. Soc. London, session 1885–'86, No. 489, p. 86.

—— —— On Carboniferous Ostracoda from the Gayton borings, Northamptonshire.

In Geol. Mag., n. s., decade 3, vol. 3, London, 1886, p. 248, pl. 7.

Kirkbya, Bythocypris, Macrocypris, Cytherella.

—— —— Notes on the Palæozoic bivalved Entomostraca. No. 22. On some undescribed species of British Carboniferous Ostracoda.

In Annals Mag. Nat. Hist., 5th series, London, vol. 18, 1886, p. 249, pls. 6–9.

Bythocypris, Cythere?, Leperditia, Beyrichia, Primitia?, Beyrichiella?, Kirkbya, Moorea, Cytherella, Bathocythere, Argillæcia, Aglaia?, Xestoleberis?, Macrocypris, Carbonia, Bairdia.

—— —— On some fringed and other Ostracoda from the Carboniferous series.

In Geol. Mag., n. s., decade 3, vol. 3, London, 1886, p. 434, pls. 11, 12.

Beyrichiopsis n. g., *Beyrichiella* n. g., *Beyrichia.*

—— On Palæozoic Phyllopoda.

In Geol. Mag., n. s., decade 3, vol. 3, London, 1886, p. 456.

Ceratiocaris.

—— —— Notes on the distribution of the Ostracoda of the Carboniferous formations of the British Isles.

In Quart. Jour. Geol. Soc. London, vol. 42, 1886, p. 496.

Beyrichiopsis, Phreatura n. g., *Youngia* n. g.

This generic name was used for a new genus of Trilobites by Lindström in 1885.

Note.—Since this paper was read many of the species have been described and figured in the Annals Mag. Nat. Hist. for October, 1886, and in the Geol. Mag. of the same date. Others in the Proc. Geologist Assoc., vol. 9, 1886.

—— Fourth report of the committee, consisting of Mr. R. Etheridge, Dr. H.

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Jones (T. Rupert)—Continued.

Woodward, and Prof. T. Rupert Jones (secretary), on the fossil Phyllopoda of the Palæozoic rocks, 1886.

In Rept. 56th Meeting Brit. Assoc. Adv. Sci., 1886, p. 229.

Ceratiocaris, Emmelezoe, Xiphocaris, Physocaris, Cryptozoe.

—— and **Kirkby** (James W.) A list of the genera and species of bivalved Entomostraca found in the Carboniferous formations of Great Britain and Ireland. With notes on the genera and their distribution.

In Proc. Geologist Assoc., vol. 9, 1886, p. 495.

I. Cypridinidæ: 1. *Cypridina*, 2. *Cypridinella*, 3. *Cypridellina*, 4. *Cypridella*, 5. *Sulcuna*, 6. *Cyprella*, 7. *Bradycinetus*, 8. *Philomedes*, 9. *Rhombina*. II. Entomoconchidæ: 1. *Entomoconchus*, 2. *Offa*. III. Polycopidæ: 1. *Polycope*. IV. Entomididæ: 1. *Entomis*. V. Cytherellidæ: 1. *Cytherella*. VI. Leperditiidæ: 1. *Leperditia*, 2. *Bernix*, 3. *Beyrichia*, 4. *Beyrichiella*, 5. *Beyrichiopsis*, 6. *Kirkbya*, 7. *Moorea*, 8. *Phreatura*. VII. Cypridideæ: 1. *Aglaia*, 2. *Candona*, 3. *Argillæcia*, 4. *Macrocypris*, 5. *Bythocypris*, 6. *Bairdia*. VIII. Dawinulidæ: 1. *Dawinula*. IX. Cytheridæ: 1. *Cythere*, 2. *Xestoleberis*, 3. *Bythocythere*, 4. *Carbonia*, 5. *Youngia*.

——, **Etheridge** (R.) and **Woodward** (H.) Fifth report of the committee, consisting of Mr. R. Etheridge, Dr. H. Woodward, and Prof. T. Rupert Jones (secretary), on the fossil Phyllopoda of the Palæozoic rocks, 1887.

In Rept. 57th Meeting Brit. Assoc. Adv. Sci., 1887, p. 60.

Ceratiocaris, Dithyrocaris, Leaia, Estheria.

—— Notes on the Palæozoic bivalved Entomostraca. No. 23. On some Silurian genera and species (continued).

In Annals Mag. Nat. Hist., 5th series, London, vol. 19, 1887, p. 117, pls. 4–7.

Macrocypris, Pontocypris, Bythocypris, Cythere, Cytherella, Primitia.

Prof. T. Rupert Jones remarks in this paper: "Now that not only *Cythere* but its allied genera have been fully elucidated in the living state, it is found that the genus does not comprehend many of the fossil forms once referred to it. Whether these really belong to the *Cytheridæ* or to the *Cypridideæ* it is often difficult to say; but the genus *Cythere* comprises very few of the smooth subovate forms, and none that have toothless hinges. Hence we find that a real *Cythere* is scarcely known in Palæozoic strata."

—— Notes on the Palæozoic bivalved Entomostraca. No. 24. On some Silurian genera and species (continued).

In Annals Mag. Nat. Hist., 5th series, London, vol. 19, 1887, p. 400, pls. 12, 13.

Thlipsura, Octonaria n. g., *Bollia, Primitia, Moorea, Xestoleberis, Achmina.*

—— Notes on some Silurian Ostracoda from Gothland. Stockholm, 1887, 8 pp.

Beyrichia, Leperditia, Primitia, Primitiopsis n. g., *Macrocypris, Bythocypris, Thlipsura, Achmina, Bursulella* n. g.

—— Notes on the Palæozoic bivalved Entomostraca. No. 25. On some Silurian Ostracoda from Gothland.

In Annals Mag. Nat. Hist., 6th series, London, vol. 1, 1888, p. 395.

Beyrichia, Leperditia, Entomis, Primitia, Primitiopsis n. g., *Macrocypris, Bythocypris, Thlipsura, Achmina, Bursulella* n. g.

—— Notes on the Palæozoic bivalved Entomostraca. No. 26. On some new Devonian Ostracoda, with a note on their geological position, by the Rev. G. F. Whidborne.

In Annals Mag. Nat. Hist., 6th series, London, vol. 2, 1888, p. 295, 1 pl.

Kyamodes n. g.

—— and **Woodward** (Henry). A monograph of the British Palæozoic Phyllopoda (Phyllocarida, Packard).

In Palæont. Soc. London, vol. 41, 1887, pt. 1.

Ceratiocaridæ.

—— —— On some Scandinavian Phyllocaridæ.

In Geol. Mag., n. s., decade 3, vol. 5, London, 1888, p. 97, pl. 5.

Ceratiocaris.

—— *and others.* Sixth report of the committee, consisting of Mr. E. Etheridge, Dr. H. Woodward, and Prof. T. Rupert Jones (secretary), on the fossil Phyllopoda of the Palæozoic rocks, 1888.

In Rept. 58th Meeting Brit. Assoc. Adv. Sci., 1888.

Ceratiocaris, Echinocaris, Equisitides, Elymocaris, Tropidocaris, Mesothyra, Dithyrocaris, Rhinocaris, Spathiocaris, Dipterocaris, Estheria, Hymenocaris, Saccocaris, Lingulocaris, Bactropus, Schizodiscus.

Author's edition, 9 pp. and 9 wood-cuts.

—— and **Woodward** (Henry). See **Woodward** (Henry) and **Jones** (T. Rupert).

—— See **Schmidt** (Fr.) and **Jones** (T. Rupert).

Jordan (H.) Ueberreste eines kleinen überaus merkwürdigen Crustacees.

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Jordan (H.)—Continued.

In Verhandl. natur. Vereins preussischen Rheinlande, Jahrg., vol. 4, 1847, p. 89, pl. 2, figs. 1, 2.

Gampsonyx (von Meyer) n. g.

—— and **Meyer** (H. von). Ueber die Crustaceen der Steinkohlenformation von Saarbrücken. Cassel, 1854, 2 pls.

Gampsonyx, Adelophthalmus (*Eurypterus*), *Chonionotus, Arthropleura.*

Jukes (F.) and **Sowerby** (J. D. C.) An account of a new species of Trilobite found in the Barr limestone in the neighborhood of Birmingham, by Frederick Jukes, with a note by J. D. C. Sowerby.

In Mag. Nat. Hist. (London), vol. 2, London, 1829, p. 41, 5 figs.; Am. Jour. Sci., 1st series, vol. 23, 1833, p. 203; Neues Jahrbuch für Mineral., 1833, p. 624.

(*Bumastes barriensis*), *Asaphus, Calymene.*

Karsten (Gustav). Die Versteinerungen des Uebergangs-Gebirges in den Geröllen der Herzogthümer Schleswig und Holstein. Kiel, 1869, 25 pls.

Olenus, Proetus, Cyphaspis, Phacops, Calymene, Lichas, Trinucleus, Ampyx, Asaphus, Isotelus, Ceraurus, Sphærexochus, Encrinurus, Nileus, Agnostus, Beyrichia, Cythere.

Kayser (Emanuel). Beiträge zur Geologie und Palæontologie der Argentinischen Republik. Cassel, 1876, 2 pls.

Olenus. Arionellus, Bathyurus?, Arethusina, Ampyx. Asaphus, Ogygia, Agnostus, Leperditia.

—— Die Fauna der ältesten Devonbildungen des Harzes.

In Abhandlungen zur geologischen Specialkarte von Preussen und den thüringischen Staaten. Vol. 2, pt. 4. Berlin, 1878. Atlas, 36 pls.

Harpes, Proetus, Cryphæus, Cyphaspis, Phacops, Dalmanites, Lichas, Acidaspis, Bronteus, Primitia, Dithyrocaris.

—— Ueber *Dalmanites rhenanus*, eine Art der *Hausmanni*-Gruppe, und einige andere Trilobiten aus den älteren rheinischen Dachschiefern.

In Zeitschr. Deutsch. geol. Gesell., vol. 32, 1880, p. 19, pl. 3.

Phacops, Cryphæus, Dalmanites.

—— *Dechenella*, eine devonische Gruppe der Gattung *Phillipsia*.

In Zeitschr. Deutsch. geol. Gesell., vol. 32, 1880, p. 703, pl. 27.

Dechenella n. g.

—— Beiträge zur Kenntniss von Oberdevon und Culm am Nordrande des rheinischen Schiefergebirges; Arten aus dem Culm von Aprath.

Kayser (Emanuel)—Continued.

In Jahrbuch Preuss. geol. Landesanst. und Bergakad., Berlin, 1881, p. 67.

Phillipsia æqualis, P. longicornis, P. eichwaldi, P. emarginata.

—— Die Orthocerasschiefer zwischen Balduinstein und Laurenberg an der Lahn. Palæontologischer Anhang.

In Jahrbuch Preuss. geol. Landesanst. und Bergakad., Berlin, 1883, p. 34, pl. 3, fig. 6.

Phacops fecundus, Cryphæus rotundifrons, C. kochi.

—— Mittel- und obersilurische Versteinerungen aus dem Gebirgsland von Tshan Tiens.

In China (Richthofen), vol. 4, Berlin, 1883, p. 37.

Asaphus, Calymene, Trinucleus richthofeni, Encrinurus.

—— Obercarbonische Fauna von Loping.

In China (Richthofen), vol. 4, Berlin, 1883, p. 161.

Phillipsia obtusicauda, pl. 19, fig. 3.

Keyes (Chas. R.) On the fauna of the Lower Coal Measures of central Iowa.

In Proc. Acad. Nat. Sci. Phila., 1888, p. 222.

Cythere nebracensis.

Kiesow (J. von). Ueber silurische und devonische Geschiebe West-Preussens.

In Schrift. nat. Gesell. Danzig, new series, vol. 6, 1884, p. 205, 3 pls.

Proetus, Phacops, Calymene, Lichas, Ampyx, Asaphus, Ptychopyge, Illænus. Acidaspis, Cheirurus, Encrinurus, Beyrichia, Leperditia, Primitia, Cytherellina.

—— Ueber gotländische *Beyrichien*.

In Zeitschr. Deutsch. geol. Gesell., vol. 40, 1888, p. 1, 2 pls.

Kinnear (W. T.) Note on the occurrence of a new Carboniferous Crustacean at Ardrois Castle, Fife.

In Trans. Edinburgh Geol. Soc., vol. 5, pt. 3, 1887, p. 417.

Dithyrocaris, Palæocrangon, Ceratiocaris, Rostrocaris n. g.

Kinsky (*Graf* von). Schreiben des H. Grafen von Kinsky an von Born über einige mineralogische und lithologische Merkwürdigkeiten.

In Abhandlungen einer Privat-Gesell. in Böhmen, vol. 1, Prag, 1775, p. 243.

Kirkby (J. W.) On some Permian fossils from Durham.

In Trans. Tyneside Nat. Field Club, vol. 3, 1858, p. 286.

—— On Permian Entomostraca from the shell limestone of Durham. With notes on the species by T. Rupert Jones.

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Kirkby (J. W.)—Continued.

In Annals Mag. Nat. Hist., 3d series, London, vol. 2, 1858, p. 317, 4 pls.

Kirkbya, Cytheridæ, Cythere, Bairdia.

—— and Jones (T. Rupert). On Permian Entomostraca.

In Trans. Tyneside Nat. Field Club, vol. 4, 1859, p. 122, 4 pls.

See, also, Jones (T. Rupert) and Kirkby (J. W.), and Jones (T. Rupert), Kirkby (J. W.), and Brady (M. P.).

—— On the Permian rocks of South Yorkshire and their Palæontological relations.

In Quart. Jour. Geol. Soc. London, vol. 17, 1861, p. 287.

Cythere (Bairdia), Kirkbya.

—— On some additional species that are common to the Carboniferous and Permian strata.

In Annals Mag. Nat. Hist., 3d series, London, vol. 10, 1862, p. 262.

Kjerulf (Theo.) Veiviser ved geologiske Exkursioner i Christiania og Omegn. Christiania, 1865.

The author herein gives a list of Norwegian Silurian fossils, with some notes and figures on the genera *Ceratopyge, Cyrtometopus, Illænus, Phacops.*

Klein (J. T.) Specimen descriptionis petrefactorum Gedanensium order Oryctographia Gedannensis, etc. (*)

In Nuremberg, 1770, folio, pl. 15, figs. 5–7.

Calymene blumenbachii.

Klöden (K. F.) Die Versteinerungen des Mark Brandenburg, etc. Berlin, 1834, 10 pls.

Cytherina phaseolus Calymene blumenbachii, C. var. *tuberculata, C.* var. *pulchella, C. sclerops, C. punctata, C. concinna, C. polytoma?, Asaphus extenuatus?, A. angustifrons, A. expansus, A. auriculatus, A. dilatatus, A.* (*Illænus*) *crassicauda, A.* (*Ampyx*) *nasutus?, A. caudatus, Battus pisiformis, B. tuberculatus,* pl. 1, figs. 16–23. F. McCoy, "Brit. Pal. Rocks," p. 135, remarks on this species that the name *Beyrichia tuberculatus* is generally applied to fig. 22 of Klöden's plate, which is a common form in the Gothland beds); *Battus gigas,* pl. 2, fig. 1.

Koch (C.) Monographie der Homalonotus-Arten des rheinischen Unterdevon.

In Preuss. geol. Landesanstalt, Abhandl., Berlin, 1883, vol. 4, pt. 2.

Koenen (A. von). Die Kulm-Fauna von Herborn.

In Neues Jahrbuch für Mineral., 1879, p. 309, pls. 6, 7.

Phillipsia, Proetus.

Koenen (A. von)—Continued.

—— Ueber die Unterseite der Trilobiten.

In Neues Jahrbuch für Mineral., 1880, vol. 1, p. 429, pl. 8, figs. 9, 10.

Phacops, Asaphus, Calymene.

—— Ueber Clymenienkalk und Mittel-Devonien bei Montpellier.

In Neues Jahrbuch für Mineral., 1886, p. 163.

Dechenella exoti.

Kolmodin (Lars). Bidrag till kännedomen om Sveriges Siluriska Ostracoder.

In Akad. Afhandling som med tillstånd af Tidtberömda Filosofiska Fakultetens i Upsala, etc., 1869, 1 pl.

Leperditia, Beyrichia, Cytheropsis, Elpe.

—— Ostracoda Silurica Gotlandiæ enumerat.

In Öfversigt kongl. Vet. Akad. Förhandlingar, 1879, No. 9, p. 133, pl. 19.

Leperditia, Beyrichia, Elpe.

König (C. E.) Icones fossilium sectiles.

Centuria prima, text, 4 pp., pls 1–8; Centuria secunda, pls. 9–19.; n. d.

The common edition of this work has only four pages of text and eight plates (London, 1820, 4to).

Calymene decipiens, p. 2, pl. 3, fig. 32 (*Ellipsocephalus hoffi*); *Asaphus myops,* p. 3, pl. 4, fig. 53; *Homalonotus* n. g., *H. knighti,* p. 4, pl. 7, fig. 85; *Agnostus,* pl. 10, figs. 119, 120; *Isotelus gigas,* pl. 10, fig. 121; *Asaphus extenuatus,* pl. 10, fig. 122; *A. crassicauda,* pl. 13, fig. 150; *Belinurus* n. g., *B. bellulus,* pl. 18, fig. 230.

For a description of the genus *Belinurus,* see W. H. Baily's article, Annals Mag. Nat. Hist., 3d series, London, vol. 11, 1863.

Koninck (L.-G. de). Mémoire sur les Crustacés fossiles de Belgique.

In Mém. Acad. Sci. Bruxelles, vol. 14, 1841, 1 pl.

Goldius n. g., *Asaphus, Cyclus* n. g., *Cytherina, Cypridina, Cyprella* n. g. (*Phillipsia* and *Bronteus*).

—— Description des animaux fossiles qui se trouvent dans le terrain carbonifère de Belgique. Liège, 1842–'44.

Cythere, Cypridina, Cyprella, Cypridella n. g., *Cyclus, Phillipsia brongniarti, P. globiceps, P. derbyensis, P. gemmulifera, P. pustulata, P. jonesii.*

—— Recherches sur les fossiles palæozoïques de la Nouvelle-Galles du Sud Australie.

In Mém. Soc. Sci. Liège, 2d series, vol. 6, 1877.

Illænus, Staurocephalus, Cheirurus Encrinurus, Oromus, Calymene, Proetus, Lichas, Bronteus, Harpes.

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Koninck (L.-G. de)—Continued.

—— Recherches sur les fossiles palæozoïques de la Nouvelle-Galles du Sud Australie.

In Mém. Soc. Sci. Liège, 2d series, vol. 7, 1878.
Phillipsia, Griffithides, Brachymetopus.

—— Sur une nouvelle espèce de crustacé du terrain houiller de la Belgique.

In Bull. Acad. Sc. Bruxelles, 2d series, vol. 45, 1878, p. 409, 1 pl.
Brachypyge carbonis.
The principal part of this article is a letter from Dr. Henry Woodward to L. G. de Koninck.

—— Notice sur le *Prestwichia rotundata* J. Prestwich, découvert dans le schiste houiller de Horme, près Mons.

In Bull. Acad. Sci. Bruxelles, 3d series, vol. 1, 1881, p. 91, 1 pl.

Krause (A.) Die Fauna der sogen. Beyrichien oder Choneten-Kalke des norddeutschen Diluviums.

In Zeitschr. Deutsch. geol. Gesell., vol. 29, Berlin, 1877, p. 1, 1 pl.
Calymene blumenbachii, Phacops downingæ, Proetus concinus, Leperditia, Beyrichia, Cytherellina, Primitia.

Kuntgen (K.) Die Trilobiten. (*)

In Mus. Luxemburg, 1877.

Kutorga (S.) Beiträge zur Kenntn. der organischen Ueberreste des Kupfersandst. am westl. Abhange des Urals. St. Petersburg, 1838, p. 22, pl. 4, figs. 1–3.

Limulus oculatus Kutorga.
Édouard d'Eichwald ("Lethæa Rossica," vol. 1, p. 1360) uses this species for a type of his new genus, *Compylocephalus.*

—— Ueber einige baltische silurische Trilobiten.

In Verhandl. russ. k. mineral. Gesell. zu St. Petersburg, 1847, p. 287, plate.
Asaphus, Illænus, Encrinurus.

—— Einige *Sphærexochus* und *Cheirurus* aus den silurischen Kalksteinschichten des Gov. St. Petersburg.

In Verhandl. russ. k. mineral. Gesell. zu St. Petersburg, 1854, p. 105, 3 pls.
Cheirurus gembnitzkii, C. macrophthalmus, Sphærexochus cranium, S. hemicranium, S. platycranium, S. enurus.

Lang (C. N.) Historia lapidum figuratorum Helvetia ejusque vicinæ in qua enarrantur omnia eorum genera, species et vires. Venetiis, 1708. (*)

—— Tractatus de origine lapidum figuratorum Helvetiæ. Lucernæ, 1709. (*)

Laspeyres (H.) Das fossile Phyllopoden-Genus *Leaia.*

In Zeitschr. Deutsch. geol. Gesell., Berlin, 1870, p. 733, 1 pl.

Latreille (P.-A.) Affinités des Trilobites.

In Mém. Mus. Hist. Nat., Bruxelles, vol. 7, 1821, p. 22; Annals Sci. Phys., Bruxelles, vol. 6.

Lawrow (N.) Zwei neue Asaphus-Arten aus dem silurischen Kalksteine.

In Verhandl. russ. k. mineral. Gesell. zu St. Petersburg, 1855–'56, p. 237, pls. 4, 5.

—— *Ptychopyge* und *Megalaspis*, Trilobiten der unter-silurischen Kalksteine.

In Verhandl. russ. k. mineral. Gesell. zu St. Petersburg, 1857–'58, p. 146, plate.

Lebesconte (M.-P.) Constitution générale du massif breton comparée à celle du Finistère.

In Bull. Soc. Géol. France, 3d series, vol. 14, 1886, p. 776, pls. 34–36.
Homalonotus barroisi, H. heberti, Ogygites.

Lehmann (J. G.) Versuch einer Geschichte von Flötzgebirgen betreffend deren Entstehung, Lage, darin befindlichen Metalle, Mineralien und Fossilien. Berlin, 1756. (*)

—— De Entrochis et Asteriis. (*)

In Novi Comm. Sci. Petropol., vol. 10, 1764, p. 429, par. 12, par. 12, figs. 8–10.

Leuchtenberg (M. H. von). Beschreibung einiger neuer Thierreste der Urwelt von Zarskoje-Selo. St. Petersburg, 1843, 2 pls.

Asaphus, Nileus, Metopias.

Lhwyd (Edward). Part of a letter from Mr. Edward Lhwyd to Doctor Martin Lister.

In Philos. Trans. Royal Soc. London, vol. 20, No. 243, 1698, p. 299, plate, figs. 8, 9 and 10.
This paper contains the earliest account of Trilobites. The author discovered two fragments and one entire specimen of *Ogygia buchii* near Llandeilo, in Carmarthenshire. Lhwyd says in his letter that he did not know what to make of these fossils. The *Ogygia* (fig. 10) he refers to the skeleton of an unknown fish. Fig. 8 represents the head of a species of the genus *Trinucleus.*

—— Lithophylacii Britannici Ichnographia. Londini, 1699, 23 pls.; 2d ed., 1760.

This work gives a catalogue of English fossils contained in the Ashmolean Museum, and also several essays on fossils. In the author's article "Epistola I. de lapidibus quibusdam Germania acceptis," pp. 95–100, he alludes to an *Ogygia*, and remarks: "This ichthyomorphous stone swims spread out on its side, although it

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Lhwyd (Edward)—Continued.

does not correspond to any specimen heretofore discovered; it does not agree in its external outline to your fossil, but represents the skeleton of the same or of a sole, only the specimen is striated on the circumference. The figure belongs to *Buglossium*, or the sole fish, except it is somewhat larger and less compressed at its extremities, but it wants the tail of a fish. We call it *Buglossam curtam strigosam*." He also gives a description and figure of *Trinucleus fimbriatum vulgare*, pl. 22, 23, on which R. I. Murchison afterwards founded the genus *Trinucleus*.

Lindaker (T. J.) Beschreibung einer noch nicht bekannten Käfermuschel. (*)

In Mayer's Sammlung phys. Aufsätze, Dresden, vol. 1, 1791, p. 37, pl. 1.

The author describes under the name of "gegitterte Käfermuschel" a *Trinucleus* from Prague.

Lindström (G.) Normina fossilium Siluriensium Gotlandiæ Laroverks program. Visby, 1867.

Proetus, Phacops, Calymene, Homalonotus, Lichas, Acidaspis, Trapelocera, Cheirurus, Deiphon, Sphærexochus, Cryptonymus, Bronteus, Bumastus, Eurypterus, Pterygotus, Ceratiocaris, Beyrichia, Leperditia, Cytheropsis.

—— List of the fossils of the Upper Silurian formation of Gothland. Stockholm, 1885.

—— Förteckning på Götland Siluriska Crustacéer.

In Öfversigt. Kongl. Vet. Akad. Förhandlingar, 1885, No. 6, p. 37, pls. 12–16.

Harpes, Proetus, Cyphaspis, Phætonides, Phacops, Calymene, Homalonotus, Lichas, Trochurus, Acidaspis, Cheirurus, Sphærexochus, Youngia n. g., *Deiphon, Encrinurus, Illænus, Bronteus, Eurypterus.*

Linnarsson (J. G. O.) Om de Siluriska bildningarne i Mellersta Westergötland. 1.

In Akad. Afhandling som med tillstånd af Vidtberömda Filosofiska Fakulten i Upsala, etc., 1866, 2 pls.

The Trilobites are grouped as follows: Phacopidæ: *Phacops*. Cheiruridæ: *Pliomera, Cyrtometopus, Sphærexochus*. Encrinuridæ: *Cybele*. Acidaspidæ: *Acidaspis*. Lichidæ: *Lichas*. Harpedidæ: *Arraphus*. Calymenidæ: *Calymene, Homalonotus*. Aulacopleuridæ: *Aulacopleura*. Liostracidæ: *Liostracus*. Olenidæ: *Paradoxides, Olenus, Peltura, Parabolina, Eurycare, Sphærophthalmus*. Remopleuridæ: *Remopleurides*. Proetidæ: *Forbesia*. Asaphidæ: *Asaphus, Megalaspis, Ptychopyge, Ogygia ?, Niobe*. Illænidæ: *Illænus, Rhodope, Nileus, Symphysurus, Æglina*. Trinucleidæ: *Trinucleus, Ampyx, Lonchodomas, Raphiophorus, Dionide*. Agnostidæ: *Agnostus*. Incertæ sedis: *Holometopus*.

Linnarsson (J. G. O.)—Continued.

The author also gives descriptions and figures of the following species: *Phacops pulchellus, Cyrtometopus latilobus, Sphærexochus laticeps, Lichas segmentatus, Ogygia ? apiculata, Illænus limbatus, Agnostus affinis.*

—— Om Vestergötlands Cambriska och Siluriska Aflagringar.

In Kongl. Svenska Vet.-Akad. Handl., vol. 8, No. 2, 1869, 2 pls.

Harpes, Remopleurides, Paradoxides, Dikelocephalus, Olenus, Triarthrus, Ceratopyge, Conocoryphe, Anomocare, Arionellus, Liostracus, Euloma, Holometopus, Prostus, Harpides, Phillipsia, Phacops, Calymene, Homalonotus, Lichas, Trinucleus, Ampyx, Dionide, Asaphus, Megalaspis, Symphysurus, Stygina, Ogygia, Niobe, Æglina, Acidaspis, Cheirurus, Sphærexochus, Staurocephalus, Pliomera, Cybele, Encrinurus, Dindymene, Nileus, Panderia, Agnostus, Leperditia, Beyrichia, Primitia.

—— Diagnoses specierum novarum e classe Crustaceorum in depositis Cambrisis et Siluricis Vestrogotiæ Sueciæ repertarum.

In Öfversigt. Kongl. Svenska Vet.-Akad. Förhandl., 1869, No. 1, p. 191.

Remopleurides, Triarthrus, Phacops, Trinucleus, Symphysurus, Ogygia, Niobe. Acidaspis, Cheirurus, Cybele, Dindymene, Panderia, Agnostus, Lichas, Leperditia, Beyrichia, Primitia, Trilobites ænigma.

—— Jemförelse mellan de Siluriska aflagringarne i Dalarne och i Vestergötland.

In Öfversigt. Kongl. Svenska Vet.-Acad. Förhandl., 1871, No. 3, p. 339.

Remopleurides, Trinucleus, Proetus, Phacops, Chasmops, Illænus, Nileus Beyrichia, Primitia.

Mere mention of occurrence.

—— Om några försteningar från Sveriges och Norges "Primordialzon."

In Öfversigt Kongl. Svenska Vet.-Akad. Förhandl., 1871, No. 6.

Paradoxides kjerulfi, pl. 16, figs. 1–3.

—— Anteckningar om den Cambrisk-Siluriska lagerserien Jemtland.

In Geol. Föreningens Stockholm Förhandl., vol. 1, No. 3, 1872, p. 34.

—— Öfversigt af Nerikes öfvergångsbildningar.

In Öfversigt Kongl. Svenska Vet.-Akad. Förhandl., 1875, No. 5, pl. 5; Sveriges Geologiska Undersökning Ser. C, No. 21, 1875.

Paradoxides, Ellipsocephalus, Leptoplastus n. g., *Beyrichia.*

—— Trilobiter från Vestergötlands Andrarum kalk.

In Geol. Föreningens Stockholm Förhandl., vol. 2, 1875, p. 491.

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Linnarsson (J. G. O.)—Continued.

—— En egendomlig Trilobitfauna från Jemtland.

In Geol. Föreningens Stockholm Förhandl., vol. 2, No. 12, 1875, p. 491, pl. 22, figs. 1–5.

Dicellocephalus billingsi, Triarthrus jemtlandicus, Remopleurides microphthalmus, Bohemilla (?) *denticulata.*

—— Två nya Trilobiter från Skånes alunskiffer.

In Geol. Föreningens Stockholm Förhandl., vol. 2, No. 12, 1875, p. 498.

Liostracus (?) *superstes, Cyclognathus* n. g., *C. micropygus.*

—— Geologiska iakttagelser under en resa på Öland.

In Geol. Föreningens Stockholm Förhandl., vol. 3, No. 2, 1876, p. 71.

—— Om faunan i lagren med *Paradoxides ölandicus.*

In Sveriges Geologiska Undersökning, Ser. C, No. 22, 1877, 2 pls.

Paradoxides, Ellipsocephalus, Conocoryphe, Agnostus.

—— Om de palæozoiska bildningarna vid Humlenäs.

In Sveriges Geologiska Undersökning, Ser. C, No. 28, 1878.

—— On the Trilobites of the Shineton shales.

In Geol. Mag., new series, decade 2, vol. 5, 1878, p. 188.

Conocoryphe, Remopleurides.

—— Om faunan i kalken med *Conocoryphe exsultans.*

In Sveriges Geologiska Undersökning, Ser. C, No. 35, 1879, 3 pls.

Paradoxides, Liostracus, Solenopleura, Conocoryphe, Agnostus.

—— Ceratopygekalk och undre graptolitskiffer på Falbygden, i Vestergötland.

In Geol. Föreningens Stockholm Förhandl., vol. 4, 1879, p. 269.

—— Om försteningarne i de Svenska lagren med Peltura och Sphærophthalmus.

In Geol. Föreningens Stockholm Förhandl., vol. 5, 1880, No. 4; Sveriges Geologiska Undersökning, Ser. C, No. 43, 1880.

Peltura, Sphærophthalmus, Anopocare, Ctenopyge n. g., *Agnostus.*

—— Promemoria lemnad af A. G. Nathorst för resa på Öland.

In Geol. Föreningens Stockholm Förhandl., vol. 5, No. 13, 1881.

—— De undre Paradoxides lagren vid Andrarum.

In Sveriges Geologiska Undersökning, Ser. C, No. 54, 1883, 4 pls.

Linné (C.) Ölandska och Gotländska resa. Stockholm och Upsal, 1745.

On p. 147, under the name of *Entomolithus paradoxus*, there is in this work a rough wood-cut of the pygidium of *Asaphus expansus* Linn.

—— Wästgöta resa förrattad år 1746. Stockholm, 1747.

On pp. 87 and 88 of this work there are some rough wood-cuts of Trilobites, probably an *Olenus* and the head of a *Paradoxides.*

—— Museum Tessinianum. Holmiæ, 1753, p. 123, pl. 3.

Entomolithus, pl. 3, fig. 2 (*Calymene tuberculatus*); E. paradoxus, pl. 3, fig. 1 (*Paradoxides tessini*).

—— Skanska resa. Stockholm, 1757, p. 121.

—— Petrificatet Entomolithus paradoxus beskrifed.

In Acta Regiæ Acad. Sci. Holmiens., vol. 21, 1759, p. 19, pl. 1, figs. 1–4.

Entomolithus paradoxus, pl. 1, fig. 1 (*Olenus spinulosus*); Entom. paradoxus β cantharidum, pl. 1, fig. 4, head (*Olenus gibbosus*); Entom. No. 3, pl. 1, fig. 3 (*Calymene blumenbachii*); Entom. No. 2, pl. 1, fig. 2 (*Encrinurus punctatus*).

—— Systema naturæ. Ed. 12. Vol. 3. Holmiæ, 1768, p. 160.

Entomolithus paradoxus α expansus (*Asaphus expansus* Linn.). E. paradoxus β cantharidum (*Olenus gibbosus* Wahl.), E. paradoxus γ pisiformis (*Agnostus pisiformis* Linn.).

Littleton (Charles). On a nondescript petrified insect.

In Philos. Trans. Royal Soc. London, vol. 46, No. 496, 1750, p. 598, pl. 1, figs. 3–12, pl. 2.

Calymene blumenbachii.

Locke (John). On *Isotelus maximus*, found near Trebers, in Adams County, Ohio.

In Second Ann. Rept. Geol. Survey Ohio (W. W. Mather), 1838, p. 247, fig. 8.

—— On a new species of Trilobite of very large size.

In Trans. Assoc. Am. Geol. and Naturalists, vol. 1, 1843, p. 221, plate.

Isotelus megistos Locke.

Dr. John Locke has herein given a new name to the species which he called *Isotelus maximus* in the Second Ohio Report. See, also, Am. Jour. Sci., 1st series, vol. 42, 1843, p. 366, 1 pl.

—— Notice of a new Trilobite.

In Am. Jour. Sci., 1st series, vol. 44, 1843, p. 346.

Ceraurus crosotus.

—— Supplementary notice of the *Ceraurus crosotus.*

In Am. Jour. Sci., 1st series, vol. 45, 1843, p. 223.

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Logan (W. E.) *Bronteus canadensis.*

In Rept. Geol. Survey Canada, 1844, p. 54, 2 figs.

—— On the tracks of an animal lately found in the Potsdam sandstone.

In Canadian Naturalist, vol. 5, 1860, p. 279.

Lossen (K. A.) Ueber *Cryphæus rotundifrons* aus dem *zorger* Schiefer des südlichen Unterharzes.

In Zeitschr. Deutsch. geol. Gesell., vol. 31, 1879, p. 215.

Cryphæus.

Lovén (S. L.) On *Calymene clavifrons* and *C. ovata.*

In Öfversigt Kongl. Svenska Vet.-Akad. Förhandl., 1845, p. 63.

—— Svenska Trilobiter.

In Öfversigt Kongl. Svenska Vet.-Akad. Förhandl., 1845, pp. 46, 104, pls. 1, 2.

Trinucleus, Proetus, Metopias, Lichas, Ceraurus, Cybele n. g.

Lungren (B.) Om den vid Ramsåsa och Öfveredskloster i Skåne forekommande sandstenens alder.

In Acta Univ. Lundensis, 1874.

Leperditia.

MacLeay (W. S.) Observations on Trilobites, founded on a comparison of their structure and that of living Crustacea.

In R. I. Murchison. "The Silurian system," London, 1839, p. 666; Annals Mag. Nat. Hist., 1st series, London, vol. 4, 1839, p. 16.

The author compares them with *Apus* and other *Aspidophora*, animals which, in his opinion, of all the *Entomostraca*, appear to come nearest to the *Trilobita*.

McCoy (Frederick). On *Entomoconchus scouli.*

In Jour. Geol. Soc. Dublin, vol. 11, 1839, p. 91, pl. 5, figs. a, c.

Entomoconchus n. g.

—— A synopsis of the characters of the Carboniferous limestone fossils of Ireland. Dublin, 1844, 29 pls.

The title-page bears no author's name. The book shows that it was prepared by Frederick McCoy, under the direction of Richard Griffith, the collector, in whose cabinet all the species were contained.

Phillipsia, Griffithides, Calymene, Dithyrocaris, Entomoconchus, Cytherina, Bairdia n. g., *Cythere, Daphina.*

—— A synopsis of the Silurian fossils of Ireland, collected from the several districts by Richard Griffith, F. G. S. The whole being named, and the new species drawn and described, by Frederick McCoy. Dublin, 1846, 5 pls.

Harpes, Remopleurides, Forbesia n. g., *Phacops, Portlockia* n. g., *Calymene, Homalonotus, Lichas, Trinucleus, Ampyx, Ogygia, Isotelus, Illænus, Acidaspis, Cheirurus, Sphærexochus, Otarion, Encrinurus, Bronteus, Trinodus* n. g., *Tiresias* n. g., *Beyrichia* n. g., *Cythere, Beyttus.*

A notice of the new genera described by Frederick McCoy is given in the Ray Society's edition of Burmeister's "Organisation of Trilobites. Supplementary appendix," p. 123.

The generic name *Tiresias* was used in 1845 for a genus of the Coleoptera, and that of *Forbesia* for one of the Polypi in 1845. *Trinodus* was used in 1846 for a genus of the Coleoptera.

—— On the fossil botany and zoology of the rocks associated with the coal of Australia.

In Annals Mag. Nat. Hist., 1st series, London, vol. 20, 1847, p. 226, plate.

Phillipsia, Brachymetopus n. g., *Cythere, Bairdia.*

—— On the classification of some British fossil Crustacea, with notices of new forms in the University collection at Cambridge.

In Annals Mag. Nat. Hist., 2d series, London, vol. 4, 1849.

Asaphinæ: 1. *Phacops*, 2. *Calymene*, 3. *Trimerocephalus* n. g., 4. *Asaphus* (subgenera, *Isotelus, Basilicus*), 5. *Illænus* (subgenera, *Illænus, Bumastus, Dysplanus*), 6. *Forbesia*, 7. *Phillipsia*. Paradoxinæ: 1. *Paradoxides* (subgenus, *Olenus*), 2. *Ceraurus*, 3. *Cryphæus*, 4. *Sphærexochus*, 5. *Acidaspis*, 6. *Staurocephalus*, 7. *Remopleurides*, 8. *Zethus*. Ogyginæ: 1. *Trinucleus* (subgenus, *Tetrapsellium*), 2. *Tretaspis* n. g., 3. *Ampyx*, 4. *Ogygia*, 5. *Bronteus*, 6. *Lichas* (subgenera, *Trochurus, Acanthopyge*). Harpedinæ: 1. *Harpes*, 2. *Harpidella* n. g., 3. *Amphion*. Agnostinæ: 1. *Trinodus*, 2. *Agnostus, Chasmops* n. g., *Griffithides, Barrandia* n. g., *Ceratiocaris* n. g., *Cytheropsis* n. g., *Pterygotus.*

Partly republished in the author's "Contributions to British Palæontology, etc.," London, 1854.

—— On the supposed fish remains figured on plate 4 of "The Silurian system."

In Quart. Jour. Geol. Soc. London, vol. 9, 1853, p. 13.

—— A synopsis of the classification of the British Palæozoic rocks, by Adam Sedgwick; with a systematic description of the British Palæozoic fossils in the Geological Museum of Cambridge, by Frederick McCoy, with figures of the new and imperfectly known species. London and Cambridge, 1855, 25 pls. Pt. 2. Palæontology.

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McCoy (Frederick)—Continued.

Fasciculus 1. Radiata and Articulata. London, 1851.

Fasciculus 2. Lower and Middle Palæozoic Mollusca. London, 1852.

Fasciculus 3. Upper Palæozoic Mollusca and fish. London and Cambridge, 1855.

Harpes, Forbesia, Phacops, Odontochile, Chasmops, Portlockia, Calymene, Homalonotus, Trochurus, Lichas, Trinucleus, Harpidella, Tretaspis, Ampyx, Isotelus, Ogygia, Barrandia, Acidaspis, Ceraurus, Eccoptochile, Staurocephalus, Encrinurus, Zethus, Illænus, Dysplanus, Diplorhina, Agnostus, Acanthopyge, Eurypterus, Pterygotus, Leptocheles n. g., *Ceratiocaris, Beyrichia, Cytheropsis, Trinodus.*

—— Contributions to British palæontology, or first description of 360 species and several genera of fossil Radiata, Articulata, Mollusca and Pisces from the Tertiary, Cretaceous, Oolitic and Palæozoic strata of Great Britain. Republished from the Annals Mag. Nat. Hist. Cambridge, 1854.

For a list of the genera of fossil Crustacea, see entries under McCoy (Frederick), Annals Mag. Nat. Hist., 2d series, London, vol. 4, 1849.

—— Geological Survey of Victoria. Prodromus of the palæontology of Victoria, or figures and descriptions of Victorian organic remains, decade 3. Melbourne and London, 1875, pls. 22, 23.

Phacops (*Odontochile*) *caudatus*, *P.* (*Portlockia*) *fecundus*, *Forbesia euryseps* McCoy, *Lichas australis* McCoy, *Homalonotus harrisoni* McCoy.

Mantell (G.) Medals of creation, or first lessons in geology and the study of organic remains. 2 vols. London, 1854.

Marcou (Jules). On the Primordial fauna and the Taconic system, by Joachim Barrande; with additional notes by Jules Marcou.

In Proc. Boston Soc. Nat. Hist., vol. 7, 1861, p. 269.

—— Notice sur les gisements des lentilles trilobitifères taconique de la Pointe Lévis ou Canada.

In Bull. Soc. Géol. France, 2d series, vol. 21, 1864, p. 236.

Marr (J. E.) On some well-defined life zones in the lower part of the Silurian (Sedgwick) of the Lake District.

In Quart. Jour. Geol. Soc. London, vol. 34, 1878, p. 871.

Appendix. On some species of *Phacops*, p. 884.

Marr (J. E.)—Continued.

—— and **Nicholson** (H. A.) The Stockdale shales.

In Quart. Jour. Geol. Soc. London, vol. 44, 1888, p. 654, pl. 16.

Harpes, Proetus, Phacops, Ampyx, Acidaspis, Cheirurus.

Martin (D. S.) A new Eurypterid from the Catskill group.

In Trans. New York Acad. Sci., vol. 2, 1882, p. 8.

This notice was based upon a cast of *Stylonurus excelsior* Hall, obtained from the Museum of Natural History, Albany, New York.

Martin (W.) Petrificata Derbiensia: a description of petrifactions collected in Derbyshire. Wigan, 1809, 4to, 53 pls.

Entomolithus oniscites (*derbiensis*), pl. 45, figs. 1–3; *Entomolithus monoculites?* (*lunatus*), pl. 45, fig. 4; *Entom. paradoxus*, from Dudley, pl. 45. fig. 3; also pl. 45*x*, fig. 3.

These fossils have been referred to the following modern genera: *Phillipsia derbiensis*, pl. 45, figs. 1–3, and pl. 45*x*, fig. 3; *Belinurus*, pl. 45, fig. 4, *Calymene blumenbachi*, pl. 45, fig. 3.

Matthew (G. F.) Illustrations of the fauna of the St. John group. No. 1. The Paradoxides; their history.

In Trans. Royal Soc. Canada, vol. 1, 1882, Sec. 4, p. 87, pl. 9.

Paradoxides etemenicus Matt., *Par. acadicus* Matt., *P. lamellatus* Hartt.

—— Illustrations of the fauna of the St. John group. No. 1. The Paradoxides (supplementary section describing the parts).

In Trans. Royal Soc. Canada, vol. 1, 1882, Sec. 4, p. 271, pl. 10.

—— Illustrations of the fauna of the St. John group, continued: On the *Conocoryphea*, with further remarks on *Paradoxides*.

In Trans. Royal Soc. Canada, vol. 2, 1884, Sec. 4, p. 99, pl. 1.

Paradoxides, Ctenocephalus, Conocoryphe.

In his explanation of the plate, fig. 6, the author uses a new subgenus, *Ctenocephalus* (*Hartella*) *matthewi*, and also for fig. 22, *Conocoryphe* (*Bailiella*) *baileyi*.

—— An outline of recent discoveries in the St. John group.

In Bull. New Brunswick Nat. Hist. Soc., No 4, 1884.

—— Illustrations of the fauna of the St. John group. No. 3. Descriptions of new genera and species (including a description of a new species of Solenopleura, by J. F. Whiteaves).

In Trans. Royal Soc. Canada, vol. 3, 1885, p. 29, 3 pls.

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Matthew (G. F.)—Continued.

Lepiditta n. g., *Lepidilla* n. g., *Beyrichia*, *Hipponicharion* n. g., *Beyrichona* n. g., *Primitia*, *Agnostus*, *Microdiscus*, *Agraulos*, *Solenopleura*, *Paradoxides*.

—— On the probable occurrence of the great Welsh *Paradoxides*, *P. davidis*, in America.

In Am. Jour. Sci., 3d series, vol. 30, 1885, p. 72; Nature, vol. 32, 1885, p. 358.

—— Abstract of a paper on the Cambrian fauna of Cape Breton and Newfoundland.

In Canadian Record Sci., vol. 2, 1886, p. 255.

—— Note on the occurrence of *Olenellus? kjerulfi* in America.

In Am. Jour. Sci., 3d series, vol. 31, 1886, p. 472.

—— On the Cambrian fauna of Cape Breton and Newfoundland.

In Trans. Royal Soc. Canada, vol. 2, 1886, p. 147.

Agraulos, *Selenopleura*.

—— Illustrations of the fauna of the St. John group. No. 4. On the smaller eyed Trilobites of Division 1, with a few remarks on the species of the higher division of the group.

In Canadian Record Sci., vol. 2, No. 6, 1887, p. 357.

—— On the kin of *Paradoxides* (*Olenellus?*) *kjerulfi*.

In Am. Jour. Sci., 3d series, vol. 33, 1887, p. 390.

—— The great Acadian Paradoxides.

In Am. Jour. Sci., 3d series, vol. 33, 1887, p. 388.

Paradoxides regina Matt.

—— Illustrations of the fauna of the St. John group. No. 4. Part 1. Description of a new species of *Paradoxides* (*P. regina*). Part 2. The smaller Trilobites with eyes (*Ptychoparidæ* and *Ellipsocephalidæ*).

In Trans. Royal Soc. Canada, vol. 5, 1887, p. 115, 3 pls.

Paradoxides, *Liostracus*, *Strenuella* n. subgen., *Ptychoparia*, *Solenopleura*, *Agraulos*, *Ellipsocephalus*.

Maurer (F.) Paläontologische Studien im Gebiet des rheinischen Devon. Die Fauna des Rotheisenstein der Grube Haina.

In Neues Jahrbuch für Mineral., 1875, p. 596, pl. 14.

Phacops latifrons, *Cyphaspis ceratophthalmus*.

Maurer (F.)—Continued.

—— Paläontologische Studien im Gebiet des rheinischen Devon. Die Thonschiefer des Ruppbachthales bei Diez.

In Neues Jahrbuch für Mineral., 1876, p. 808, pl. 14.

Phacops, *Acidaspis*, *Bronteus*.

—— Die Fauna der Kalke von Waldgirmes bei Giessen.

In Abhandl. grossh.-hess. geol. Landesanstalt zu Darmstadt, vol. 1, pt. 2, 1885, atlas of 11 pls.

Harpes, *Phacops*, *Prostus*, *Cyphaspis*, *Cheirurus*, *Bronteus*, *Primitia*, *Orozoe*.

Meek (F. B.) Note on *Belinurus danæ*, from the Illinois Coal Measures.

In Am. Jour. Sci., 2d series, vol. 43, 1867, p. 257; Geol. Survey Illinois, vol. 2, p. 395.

—— Note on a new genus of fossil Crustacea.

In Am. Jour. Sci., 2d series, vol. 43, 1867, p. 394; Geol. Survey Illinois, vol. 3, p. 547.

Euproops (n. g.).

—— Descriptions of fossils collected by the U. S. Geological Survey, under charge of Clarence King.

In Proc. Acad. Nat. Sci. Phila., vol. 22, 1870, p. 56.

Republished and illustrated in Rept. U. S. Geol. Expl., 40th Parallel, vol. 4, pt. 1, pp. 1–197, pls. 1–17.

Paradoxides, *Conocoryphe* (*Conocephalites*), *Olenus*.

—— Descriptions of new species of invertebrate fossils from the Carboniferous and Devonian rocks of Ohio.

In Proc. Acad. Nat. Sci. Phila., vol. 23, 1871, p. 57.

Republished and figured in "Palæontology of Ohio," vol. 1, 1873, p. 233, 23 pls.

Proetus planimarginatus, *Dalmanites ohioensis*.

—— Descriptions of new Western Palæozoic fossils, mainly from the Cincinnati group of the Lower Silurian series of Ohio.

In Proc. Acad. Nat. Sci. Phila., vol. 23, 1871, p. 308.

Redescribed and illustrated in "Palæontology of Ohio," vol. 2, 1875.

Cythere, *Ceratiocaris* (*Colpocaris*), *Archæocaris*, *Solenocaris*, *Colpocaris*. (Not *Solenocaris* Young, 1868.)

—— List of Carboniferous fossils from West Virginia, with descriptions of new species.

In Appendix B, Rept. of Regents of West Virginia Univ., 1870, Wheeling, 1871, p. 68.

Phillipsia stevensoni Meek.

—— Final report of the U. S. Geological Survey of Nebraska and portions of the

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Meek (F. B.)—Continued.

adjacent Territories, by F. V. Hayden, etc. Report on the palæontology of eastern Nebraska, with some remarks on the Carboniferous rock of that district by F. B. Meek. Washington, 1871, p. 83, 11 pls. (Two editions: first in 8vo, second in 4to.)

Phillipsia, Cythere.

—— Genus *Archæocaris.*

In Proc. Acad. Nat. Sci. Phila., vol. 24, 1872, p. 325.

—— Description of new species of fossils from Cincinnati group, Ohio.

In Am. Jour. Sci., 3d series, vol. 3, 1873, p. 423.

Proetus, Dalmanites.

—— Preliminary palæontological report, consisting of list and descriptions of fossils, with remarks on the age of the rocks in which they are found, etc.

In Sixth Ann. Rept. U. S. Geol. Survey Territories, embracing portions of Montana, Idaho, Wyoming, and Utah, etc. F. V. Hayden, Washington, 1873, p. 431.

Conocoryphe (Ptychoparia), Bathyurus, Bathyurella (Asaphiscus) n. sg., *Asaphus, (Megalaspis), Agnostus.*

—— Report of the Geological Survey of Ohio. Vol. 1. Geology and palæontology. Pt. 2. Palæontology. Descriptions of invertebrate fossils of the Silurian and Devonian systems, by F. B. Meek.

Columbus, 1873. pp. 1-243, pls. 1-23.

Proetus, Dalmanites, Calymene, Asaphus (Isotelus), Acidaspis, Ceraurus, Illænus (Bumastus), Cythere, Leperditia.

—— Descriptions of *Olenus (Olenellus) gilberti* and *Olenus (Olenellus) howelli.*

In Rept. Geog. and Geol. Expl. Surveys West 100th Mer., vol. 3, Washington, 1875, p. 182.

—— A report on some of the invertebrate fossils of the Waverly group and Coal Measures of Ohio.

In Rept. Geol. Survey Ohio. Vol. 2. Geology and Palæontology. Pt. 2. 1875, pp. 269-347, pls. 10-20.

Phillipsia, Griffithides, Ceratiocaris (Colpocaris), Ceratiocaris (Solenocaris), Archæocaris, Colpocaris, Solenocaris.

—— Palæontology.

In U. S. Geol. Expl. 40th Parallel, vol. 4, pt. 1, 1877, pp. 1-197, pls. 1-17.

Paradoxides, Conocoryphe (Ptychoparia), Proetus, Dalmanites.

—— and **Hayden** (F. V.) Descriptions of new Lower Silurian, Jurassic, Cretaceous, and Tertiary fossils collected in

Meek (F. B.) and **Hayden** (F. V.)—Continued.

Nebraska by the exploring expedition under the command of Capt. W. F. Raynolds, U. S. Top. Eng., with remarks on the rocks from which they were obtained.

In Proc. Acad. Nat. Sci. Phila., vol. 13, 1862, p. 415.

Arionellus, Arionellus (Crepicephalus) oweni.

—— —— Palæontology of the Upper Missouri. A report upon collections made principally by the expeditions under command of Lieut. G. K. Warren, U. S. Top. Eng., in 1855-'56. Invertebrates. Pt. 1.

In Smithsonian Contrib., No. 172, Washington, 1864, 5 pls.

Paradoxides, Agraulos, Agraulos oweni M. & H.

—— and **Worthen** (A. H.) Notice of some new types of organic remains from the Coal Measures of Illinois.

In Proc. Acad. Nat. Sci. Phila., vol. 17, 1865, p. 41.

Acanthotelson n. g., *Belinurus, Anthrapalæmon, Palæocaris* n. g.

—— —— Contributions to the palæontology of Illinois and other Western States.

In Proc. Acad. Nat. Sci. Phila., vol. 17, 1865, p. 245.

Proetus, Phillipsia, Griffithides, Dalmania, Lichas.

—— —— Descriptions of invertebrates from the Carboniferous system.

In Geol. Survey Illinois, vol. 2, 1866, p. 145, pls. 14-20, 23-32.

Belinurus, Acanthotelson, Palæocaris, Anthrapalæmon.

—— —— Preliminary notice of a scorpion, a *Eurypterus*, and other fossils from the Coal Measures of Illinois.

In Am. Jour. Sci., 2d series, vol. 46, 1868, p. 19. Republished and illustrated in "Geol. Survey Illinois," vol. 3, p. 560.

—— —— Palæontology.

In Geol. Survey Illinois, vol. 3, 1868, pp. 291-565, pls. 1-20.

Proetus, Phacops, Dalmanites (Odonocephalus), Lichas, Acidaspis, Illænus, Ceratiocaris, Euproops, Palæocaris, Eurypterus (Anthrapalæmon), Acanthotelson.

—— —— Descriptions of a new species and genera of fossils from the Palæozoic rocks of the Western States.

In Proc. Acad. Nat. Sci. Phila., 2d series, vol. 14, 1870, p. 22.

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Meek (F. B.) and **Worthen** (A. H.)—Continued.

Phillipsia tuberculata M. & W., *Phillipsia* (*Griffithides*) *bufo* M. & W., *Asaphus* (*Isotelus*) *vigilans* M. & W., *Illænus* (*Bumastus*) *graftonensis* M. & W., *Dithyrocaris carbonarius* M. & W.

—— —— Descriptions of invertebrates from the Carboniferous system.

In Geol. Survey Illinois, vol. 5, 1873, pp. 323–619, pls. 1–32.

Phillipsia (*Griffithides*) *portlocki*, *Phillipsia* (*Griffithides*) *bufo*, *Phillipsia* (*Griffithides*) *scitula*, *Dithyocaris carbonarius*.

—— —— Description of the invertebrates.

In Geol. Survey Illinois, vol. 6, 1875, pp. 489–532, pls. 23–33.

Lichas, *Asaphus* (*Isotelus*), *Sphærexochus*, *Illænus* (*Bumastus*).

Meneghini (Giuseppe). Nuovi fossili siluriani di Sardegna.

In Atti reale Accad. Lincei, Roma, 1880, 1 pl.

Dalmanites, *Lamarmora*.

—— Posizione relativa dei varii piani siluriani dell' Iglesiente in Sardegna.

In Proc. verb. Soc. Toscana Sci. Nat., 1881, p. 258.

Paradoxides, *Trinucleus*, *Dalmanites*, *Conocephalites*.

—— Fauna Cambriana dell' Iglesiente in Sardegna.

In Proc. verb. Soc. Toscana Sci. Nat., 1881, p. 158.

Paradoxides, *Olenus*, *Conocephalites*.

—— Nuovi Trilobiti di Sardegna.

In Proc. verb. Soc. Toscana Sci. Nat., 1881, p. 200.

Paradoxides, *Conocephalites*.

—— Note alla fauna Cambriana dell' Iglesiente.

In Proc. verb. Soc. Toscana Sci. Nat., 1882, p. 7.

Olenus, *Anomocare*, *Conocephalites*, *Platypeltis*.

—— Nuovi fossili Cambriani di Sardegna.

In Proc. verb. Soc. Toscana Sci. Nat., 1884, p. 56.

Conocephalites, *Anomocare*.

—— Palæontologia dell' Iglesiente in Sardegna. Fauna Cambriana trilobiti.

In Mem. R. Com. Geol. Italia, vol. 3, 1888, pt. 2, 49 pp., 7 pls.

Paradoxides, *Olenus*, *Anomocare*, *Conocephalites*, *Asaphus* (*Platypeltis*), *Conocoryphe*.

Meyer (H. von). Beiträge zur Petrefacten-Kunde.

In Nova Acta Acad. Leop. Carol., vol. 15, 1831, p. 57, pl. 56, fig. 13. See, also, Neues Jahrbuch für Mineral., 1833, p. 481.

Calymene æqualis Meyer.

Meyer (H. von) and **Münster** (G. G. zu). Beiträge zur Petrefacten-Kunde. Bayreuth, 1840, pt. 3, pl. 5.

Calymene variolaris, *C. intermedia*, *C. lævis*, *C. sternbergi*, *C. propinqua*, *C. articulata*, *Asaphus*? *caudori*, *A. pusillus*, *A.*? *brevis*, *A. grandis*, *Illænus perovalis*?, *Paradoxides brevimucronatus*, *Brontes radiatus*, *B. costatus*, *B. subradiatus*, *Bumastus frankonicus*, *B. planus*, *Harpes speciosus*, *Trinucleus gracilis*, *T. wilkensii*, *T. ellipticus*, *T. nelsoni*, *T.*? *otarion*, *T.*? *gibbosus*, *Agnostus pisiformis*.

—— —— Beiträge zu Petrefacten-Kunde. Bayreuth, 1842, pt. 5, p. 112. Nachtrag zu den Versteinerungen des Uebergangs-Kalkes mit Clymenien von Oberfranken vom Herausgeber.

Calymene marginata, pl. 10, fig. 6; *C. furcata*, *Asaphus dubius*, *Ellipsocephalus hoffi*, *Otarion elegans*, *Harpes*, *Trinucleus*? *lævis*, *T. intermedius*, *T. nilsoni*.

—— Squaliden-Reste aus dem Posidonomyen-Schiefer des Oberharzes bei Ober-Schulenburg.

In Dunker and von Meyer "Palæont.," vol. 3, Cassel, 1854, p. 53.

Harpes, *Proetus*, *Phacops*, *Lichas*, *Cheirurus*.

See, also, Jordon (H.) and Meyer (H. von).

Mickleborough (John). Locomotory appendages of Trilobites.

In Jour. Cincinnati Soc. Nat. Hist., vol. 6, 1883, p. 200, figs. 1–3. Noticed: Am. Jour. Sci., 3d series, vol. 27, 1884, p. 409; Geol. Mag., n. s., decade 3, vol. 1, London, 1884, p. 80.

Asaphus megistos Locke.

Miller (S. A.) Monograph of the Crustacea of the Cincinnati group.

In Cincinnati Quart. Jour. Sci., vol. 1, 1874, p. 115.

Triarthrus, *Proetus*, *Dalmanites*, *Calymene*, *Lichas*, *Trinucleus*, *Asaphus*, *Isotelus*, *Acidaspis*, *Ceraurus*, *Beyrichia*, *Leperditia*, *Cythere*.

The author, in his classification and generic descriptions, has generally followed McCoy ("Brit. Palæozoic Rocks," 1855). He gives a description of the different fossil Crustacea occurring in the Cincinnati group, and figures *Leperditia byrnesi* Miller, and a wood-cut representing the tracks of an *Asaphus* (?).

—— [No title.—Description of new species of Palæozoic Entomostraca.]

In Cincinnati Quart. Jour. Sci., vol. 1, 1874, p. 232.

Beyrichia duryi, *B. striato-marginatus*, *B. chambersi*.

—— Some new species of fossils from the Cincinnati group, and remarks upon some described forms.

In Cincinnati Quart. Jour. Sci., vol. 2, 1875, p. 349, figures.

Acidaspis, *Beyrichia*, *Leperditia*.

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Miller (S. A.)—Continued.

—— The American Palæozoic fossils. A catalogue of the genera and species, with names of authors, dates, places of publication, group of rocks in which found, and the etymology and signification of the words, etc. Cincinnati, 1877. Also a 2d ed., with supplement.

—— Description of a new genus and eleven new species of fossils, with remarks upon others well known, from the Cincinnati group.

In Jour. Cincinnati Soc. Nat. Hist., vol. 1, 1878–'79, p. 100, pl. 3.

Lichas harrisi, *Cythere irregularis*.

—— Description of two new species from the Niagara group, and five from the Keokuk group.

In Jour. Cincinnati Soc. Nat. Hist., vol. 2, 1879, p. 254, pl. 15.

Encrinurus egani.

—— Description of new species of fossils.

In Jour. Cincinnati Soc. Nat. Hist., vol. 4, 1881, p. 259, pl. 6.

Leperditia cæcigena.

—— Description of three new species, and remarks upon others.

In Jour. Cincinnati Soc. Nat. Hist., vol. 5, 1882, p. 116, pl. 5.

Calymene callicephala Green.

Milne-Edwards (H.) Sur les affinités des Trilobites.

In Institut de France, Acad. Royale Sci., vol. 1, 1827, p. 254.

—— Trilobites dans Lamarck's "Histoire naturelle des animaux sans vertèbres." Vol. 5. Paris, 1838, p. 220.

Paradoxides, *Ellipsocephalus*, *Conocephalus*, *Triarthrus*, *Calymene*, *Ampyx*, *Asaphus*, *Ogygia*, *Otarion*, *Agnostus*, *Ceraurus*, *Cypridina* n. g.

—— Histoire naturelle des Crustacés, comprenant l'anatomie, la physiologie et la classification de ces animaux. [3 vols., with atlas of plates.] Paris, 1834–'40.

The Trilobites are described in vol. 3, pp. 295–346, in the following order: *Nileus*, *Ampyx*, *Isotelus*, *Asaphus*, *Homalonotus*, *Calymene*, *Pleurascanthe* n. g. (referred by author to *Dalmanites*), *Trinucleus*, *Otarion*, *Ogygia*, *Paradoxides*, *Peltura* n. g. (the first species cited by the author under this new genus was: *Peltura scarabæoides* Wahlenburg; the second, *Peltura bucklandi* Milne-Edwards, is a species of the genus *Lichas*), *Agnostus*, *Eurypterus*. Classifies 64 species under 13 genera.

—— Report on the palæontological researches of M. Marie Ronault in Brittany and Anjou.

Milne-Edwards (H.)—Continued.

In Comptes Rendus Acad. Sci. Paris, 1847, vol. 24, p. 593; Bull. Soc. Géol. France, vol. 4, 1847, p. 309; Quart. Jour. Geol. Soc. London, vol. 4, 1848, pt. 2, Miscellaneous, p. 35.

Trinucleus, *Calymene*, *Phacops*, *Polyeres* n. g., *Prionocheilus*, *Cheirurus*, *Nileus*, *Ogygia*, *Illænus*.

—— Structure des Trilobites.

In Annales Sci. Nat., vol. 12, 1881, 38 pp., pls. 1–3.

A review of C. D. Walcott's "Organization of Trilobites."

Acidaspis, *Calymene*, *Ceraurus*, *Trinucleus*, *Asaphus*, *Eurypterus*.

Mitchell (John). On some new Trilobites from Bowning, N. S. W.

In Proc. Linnean Soc. New South Wales, 2d series, vol. 2, 1887, p. 435, pl. 16.

Proetus bowningensis, *Cyphaspis bowningensis*, *Bronteus longispinifer*.

—— On a new Trilobite from Bowning.

In Proc. Linnean Soc. New South Wales, 2d series, vol. 3, 1888, p. 397, pl. 16 of vol. 2.

Acidaspis longispinis.

Mitchell (Samuel L.) An account of the impressions of a fish in the rocks of Oneida County, New York.

In Am. Monthly Mag., vol. 3, 1818, p. 291.

The author states that the New York fossil, from the town of Westmoreland, "is separated into plates, like those of an insect or crustaceous animal, reaching from side to side quite across the back. Eleven entire plates and part of the twelfth can be counted. They are not so broad near the head and thorax as they are on approaching the tail; for between the pectoral fins they fall short of a quarter of an inch, while on approaching the caudal fin they gradually enlarge until they exceed that measure."

Eurypterus remipes De Kay.

Modeer (A.) Anmerkungen über einige nerikische Versteinerungen. (*)

In Berlin. Gesell. naturf. Freunde, vol. 6, 1785, p. 247, pl. 2, figs. 1–8–12.

(*Agnostus pisiformis*), pl. 2, figs. 1, 2; (*Olenus gibbosus*), pl. 2, figs. 3–5; (*Olenus scarabæoides*), pl. 2, fig. 7.

Möller (Valerian von). Ueber die Trilobiten der Steinkohlenformation des Ural, nebst einer Uebersicht und einigen Ergänzungen der bisherigen Beobachtungen über Kohlen-Trilobiten im Allgemeinen. Moscou, 1867. 1 pl.

In Bull. Soc. Imp. des Naturalistes Moscou, No. 1, 1867.

Griffithides, *Phillipsia*, *Brachymetopus*.

Morris (J.) Catalogue of British fossils. London, 1843. 2d ed., London, 1854.

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Mortimer (C.) The description and figures of a small, flat, spheroidal stone having lines formed on it.

In Philos. Trans. Royal Soc. London, vol. 46, 1760, p. 602, pls. 1, 2.

(*Calymene blumenbachi.*)

Müller (O. F.) Entomostraca seu insecta testacea quæ in aquis Daniæ et Norwegiæ reperit, etc. Lipsiæ et Hafniæ, 1785. 21 pls.

Cythere n. g.

The generic term *Cytherina* was substituted by Lamarck for Müller's *Cythere*, and has been used by many authors. Prof. J. D. Dana uses the term *Cytherina* to represent a subgenus.

Münster (G. G.) Ueber einige fossile Arten *Cypris* und *Cythere*.

In Jahrbuch für Mineral., 1830, p. 60.

Cythere hissingeri.

—— and **Meyer** (H. von). See **Meyer** and **Münster**.

Murchison (R. I.) The Silurian system, founded on geological researches in the counties of Salop, Hereford, Radnor, etc. [London, 2 vols., 1839, 40 pls., and 3 large maps in folio.]

Calymene, Homalonotus, Asaphus, Ogygia, Illænus, Bumastus n. g., *Acidaspis* n. g., *Trinucleus* n. g., *Agnostus.*

—— Metamorphosis of certain Trilobites as recently discovered by M. Barrande.

In Rept. 19th Meeting Brit. Assoc. Adv. Sci., 1849, Trans. Sec., p. 58.

—— On the Silurian rocks of the south of Scotland, with a list and description of the Silurian fossils of Ayrshire, by J. W. Salter.

In Quart. Jour. Geol. Soc. London, vol. 7, 1851, p. 137, pls. 8–10.

Cheirurus gelasinosus Port., *Asaphus* sp.?, *Calymene blumenbachi* Brong., *Phacops stokesii* Milne-Edwards, *Illænus bowmani?*, *Lichas laxatus* McCoy, *Encrinurus punctatus* Brün.

—— Siluria. A history of the oldest rocks in the British Isles and other countries. [London, 1854, geol. map, 37 pls. 3d ed., London, 1859, geol. map, 41 pls. 4th ed., London, 1867, geol. map, 42 pls.]

The figures are all transferred from the original plates in the "Silurian system." In every case where the old name has been changed, in accordance with more recent nomenclature, the name used in the original work is inserted in brackets.

——, **Verneuil** (E. de) and **Keyserling** (Alex. von). Geology and palæontology of Russia and the Ural Mountains.

Murchison (R. I.) and **Verneuil** (E. de)—Continued.

[London, 1845, 2 vols., 50 pls. Palæontology, vol. 2; Crustacea, p. 376, pl. 27.]

Asaphus expansus Dalm., *Phillipsia eichwaldi* Fischer, *P. ouradica* n. s., *Calymene odeni* Eichw., *C. fischeri* Eichw.

Nathorst (A. G.) Om lager-följden inom Cambriska formationen vid Andrarum i Skåne.

In Öfversigt kongl. Svenska Vet.-Akad. Förhandl., 1869, No. 1, p. 61.

—— Om de Kambriska och Siluriska lagren vid Kiviksesperid i Skåne jemte anmärkningar om primordial faunans lager vid Andrarum.

In Geol. Föreningens Stockholm Förhandl., No. 37, vol. 3, 1876.

—— Om det inbördes förhållandet af lagren med *Paradoxides ölandicus* och *P. tessini* på Öland.

In Geol. Föreningens Stockholm Förhandl., No. 69, vol. 5, 1881.

—— Om det inbördes åldersförhållandet mellan zonerna med *Olenellus kjerulfi* och *Paradoxides ölandicus.*

In Geol. Föreningens Stockholm Förhandl., No. 71, vol. 6, 1882.

—— The position of the Olenellus beds.

In Am. Geol., vol. 2, 1888, p. 356.

Newberry (J. S.) China, by Ferdinand F. von Richthofen. Vol. 4. Berlin, 1883.

In Am. Jour. Sci., 3d series, vol. 26, 1883, p. 152.

This is a notice of the palæontological volume.

Nicholson (H. A.) A manual of palæontology for the use of students, with a general introduction on the principles of palæontology, in two volumes. Vol. 1. Edinburgh and London, 1879. Crustacea, Chapter XVIII.

Harpes, Remopleurides, Paradoxides, Anopolenus, Dicellocephalus, Hydrocephalus, Olenus, Parabolina, Triarthrus, Bohemilla, Conocephalites, Angelina, Ellipsocephalus, Sao, Proetus, Arethusina, Phillipsia, Griffithides, Bathymetopus, Phacops, Dalmanites, Calymene, Homalonotus, Lichas, Trinucleus, Ampyx, Dionide, Æglina, Asaphus, Ogygia, Barrandia, Niobe, Nileus, Stygina, Illænus, Acidaspis, Cheirurus, Sphærexochus, Areia, Placoparia, Cromus, Encrinurus, Cybele, Dindymene, Bronteus, Agnostus, Microdiscus, Protichnites, Aristozoe, Beyrichia, Leperditia, Primitia, Entomis, Cythere, Eurypterus, Pterygotus, Isochilina, Cypris, Candona, Orozoe, Callizoe, Kirkbya, Moorea, Orypridina, Cytherella, Cytherellina, Æchmina,

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Nicholson (H. A.) - Continued.

Bairdia, Hymenocaris, Caryocaris, Peltocaris, Discinocaris, Aptychopis, Pterocaris, Cryptocaris, Ceratiocaris, Dithyrocaris, Aspidocaris, Estheria, Pellocephalus, Hemiaspis, Exapinurus, Pseudoniscus, Stylonurus, Neolimulus, Prestwichia, Belinurus.

—— and **Etheridge, jr.** (R.) A monograph of the Silurian fossils of the Givan District, in Ayeshire, etc. Vol. 1, 1878-'80, 24 pls.

Fasciculus I. Rhizopoda, Actinozoa, and Trilobites (1878).

Phacops, Calymene, Lichas, Dindymene, Asaphus, Ogygia, Acidaspis, Cheirurus, Sphærexochus, Encrinurus, Cybele, Zethus, Atractopyge.

Fasciculus II. Trilobita, Phyllopoda, Cirripedia, and Ostracoda (1879).

Remopleurides (Caphyra), Proetus, Cyphaspis, Phacops, Calymene, Lichas, Trinucleus, Ampyx, Salteria, Asaphus, Illænus, Cheirurus, Acidaspis, Encrinurus, Cybele, Bronteus, Agnostus, Bronteopsis, Lonchodomus, Raphiophorus, Solenocaris, Pinnocaris, Peltocaris, Dictyocaris, Turrilepas, Beyrichia, Primitia, Cythere, Entomis.

Fasciculus III. The Annelida and Echinodermata, with supplements on the Protozoa, Cœlenterata, and Crustacea (1880).

Trinucleus, Dionide, Cyclopyge, Staurocephalus, Agnostus, Turrilepas.

Nieszkowski (J.) Der *Eurypterus remipes* aus den ober-silurischen Schichten der Insel Oesel.

In Archiv Naturk. Liv-, Ehst- u. Kurl., vol. 2, 1856, p. 299, 2 pls.

—— Versuch einer Monographie der in den silurischen Schichten der Ostseeprovinzen vorkommenden Trilobiten.

In Archiv Naturk. Liv-, Ehst- u. Kurl., vol. 1, 1857, p. 517, 3 pls.

Proetus, Cyphaspis, Phacops, Calymene, Lichas, Asaphus, Illænus, Cheirurus, Sphærexochus, Amphion, Encrinurus, Zethus, Bronteus, Platymetopus.

—— Zusätze zur Monographie der Trilobiten der Ostseeprovinzen, nebst der Beschreibung einiger neuen ober-silurischen Crustaceen.

In Archiv Naturk. Liv-, Ehst- u. Kurl., vol. 1, 1859, p. 345, 2 pls.

Cyphaspis, Lichas, Asaphus, Cheirurus, Sphærexochus, Encrinurus, Bronteus, Bunodes, Exapinurus n. g., *Pseudoniscus* n. g.

Novák (Ottomar). Studien an Hypostomen böhmischer Trilobiten. No. 1.

In Sitzungsberichte k. böhm. Gesell. Wiss., Jahrg. 1879, p. 475.

Novák (Ottomar)—Continued.

Harpes, Paradoxides, Conocephalites, Proetus, Dalmanites, Trinucleus, Ampyx, Acidaspis, Cheirurus, Placoparia, Bronteus, Carmon, Harpina n. g., *Calymene, Illænus, Phacops.*

—— Studien an Hypostomen böhmischer Trilobiten. No. 2.

In Sitzungsberichte k. böhm. Gesell. Wiss., Jahrg. 1884, 1 pl.

Harpes, Harpina, Asaphus, Ogygia, Niobe.

—— Zur Kenntniss der böhmischen Trilobiten.

In Beiträge zur Palæontolographie von Oesterrich, Wien, 1884, 5 pls.

Harpes, Remopleurides, Phillipsia, Dalmanites, Calymene, Homalonotus, Æglina, Trinucleus, Ampyx, Dionide, Asaphus, Barrandia, Ptychocheilus, Illænus, Acidaspis, Cheirurus, Placoparia, Cromus, Bronteus, Agnostus.

—— Studien an Hypostomen böhmischer Trilobiten. No. 3.

In Sitzungsberichte k. böhm. Gesell. Wiss., Jahrg. 1885, p. 581, 1 pl.

Phillipsia, Phillipsinella n. g.

—— Remarques sur le genre *Aristozoe* Barrande.

In Sitzungsberichte k. böhm. Gesell. Wiss., Jahrg. 1885, p. 239, 1 pl.

Aristozoe, Callizoe, Ceratiocaris, Orozoe.

—— Nouveau Crustacé phyllocaride de l'étage F-f_2 en Bohême.

In Sitzungsberichte k. böhm. Gesell. Wiss., Jahrg. 1885, p. 343, 1 pl.

Ptychocaris n. g.

—— Studien an Hypostomen böhmischer Trilobiten. No. 4.

In Sitzungsberichte k. böhm. Gesell. Wiss., Jahrg. 1886, p. 429, plate.

Encrinurus, Cromus.

—— Zur Kenntniss der Fauna der Étage F-f_1 in der palæozoischen Schichtengruppe Böhmens.

In Sitzungsberichte k. böhm. Gesell. Wiss., Jahrg. 1886, p. 660, 2 pls.

Aristozoe.

—— Note sur Phasganocaris, nouveau Phyllocaride de l'étage F-f_2 en Bohême.

In Sitzungsberichte k. böhm. Gesell. Wiss., Jahrg. 1886, p. 498, 1 pl.

Phasganocaris n. g.

Oehlert (D.) Sur les fossiles dévoniens du département de la Mayenne.

In Bull. Soc. Géol. France, 3d series, vol. 5, 1877, p. 578, pl. 9.

Cryphæus michelini, C. jonesi, C. munieri, Homalonotus gervillei, Leperditia britannica, Primitia fischeri.

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Oehlert (D.) Sur le Dévonien du département de la Sarthe.

In Bull. Soc. Géol. France, 3d series, vol. 7, 1879, p. 697, pl. 13.

Proetus guerangeri, *Bronteus verneuili*.

—— Description de *Goldius gerville* Barrande.

In Bull. Soc. d'Études Sci., Angers, 1885, 1 pl.

—— Études sur quelques Trilobites du groupe des Proetidæ.

In Bull. Soc. d'Études Sci., Angers, 1885, 2 pls.

The author divides the Proetidæ into two divisions on the form of the glabella.

Sec. A. Glabella conic, genera *Proetus*, *Phæton*, *Dechenella*, and *Brachymetopus*.

Sec. B. Glabella pyriform, genera *Phillipsella*, *Phillipsia*, and *Griffithides*.

Harpes, *Conocephalites*, *Cyphaspis*, *Arethusina*, *Calymene*, *Asaphus*, *Ogygia*, *Bronteus*.

—— Études sur quelques fossiles dévoniens de l'ouest de la France.

In Bibliothèque de l'École des Hautes Études, Sec. Sci. Nat., vol. 33, 1887, 5 pls.

Proetus oehlerti Bayle, *Phacops portieri* Bayle.

Oldham (J.) On *Griffithides globiceps*.

In Jour. Geol. Soc. Dublin, vol. 3, pt. 3, 1846, p. 188, pl. 2.

Redrawn, pl. 6, fig. 1 a, b, Woodward's "Monograph British Carboniferous Trilobites," London, 1883.

Ordway (Albert). On the supposed identity of *Paradoxides harlani* Green with *P. spinosus* Boeck.

In Proc. Boston Soc. Nat. Hist., vol. 8, 1861, p. 1, 2 figs.

—— The organization of the Trilobites.

In Geol. Nat. Hist. Repertory, vol. 1, 1865, p. 12.

Owen (D. D.) Report of a geological exploration of part of Iowa, Wisconsin, and Illinois, made under instructions from the Secretary of the Treasury of the United States, in the autumn of the year 1839. Washington, 1840.

In 26th Cong., H. of Rep., Doc. 239, 2d ed., 1844; 28th Cong., Sen. Doc. 407, 18 pls. of fossils.

Pl. 12, fig. 3, *Calymene bufo*; pl. 16, fig. 1, *Illænus trentonensis?* (referred by Dr. D. D. Owen, in 1852, to *Illænus ovalis*); pl. 17, fig. 9, *Thaleops?*; pl. 18, fig. 2, *Asaphus*; pl. 18, fig. 10 (*Asaphus platycephalus*); pl. 18, fig. 2, *Asaphus*.

—— Report of a geological reconnoissance of the Chippewa Land District of Wisconsin and incidentally of a portion of the Kickapoo country, and a part of Iowa and of the Minnesota territory, etc. Washington, 1848.

Owen (D. D.)—Continued.

This report contains figures of the following fossils, which were afterwards described by Dr. D. D. Owen under the names of *Dikelocephalus minnesotensis*, pl. 7, figs. 2, 3; *Lonchocephalus hamulus*, pl. 7, fig. 5; *Dikelocephalus iowensis*, pl. 7, fig. 1.

—— Report of a geological survey of Wisconsin, Iowa, and Minnesota, and, incidentally, a portion of Nebraska Territory. Philadelphia, 1852, 638 pp., 27 pls., 16 sections and maps.

Dikelocephalus n. g., *Lonchocephalus* n. g., *Crepicephalus* n. g., *Menocephalus* n. g., *Asaphus* (*Isotelus*) *iowensis*.

Owen (Richard). Description of the impressions and foot-prints of the *Protichnites* from the Potsdam sandstone of Canada.

In Quart. Jour. Geol. Soc. London, vol. 8, 1852, p. 214, pls. 9–14a.

—— Palæontology, or a systematic summary of extinct animals and their geological relation. Edinburgh, 1861.

Class 3. Crustacea, pp. 45–51.

Pacht (R.) Geognostische Untersuchungen zwischen Orel Woronasch und Simbirsk im Jahre 1853.

In Beiträge zur Kenntniss des russischen Reiches und der angränzenden Länder Asiens, St. Petersburg, 1858.

Packard, jr. (A. S.) On the embryology of *Limulus polyphemus*.

In Proc. Am. Assoc. Adv. Sci., 1870, 19th meeting, p. 247.

Notes on the larva of Trilobites, etc.

—— The structure of the eye of Trilobites.

In Am. Naturalist, vol. 14, 1880, p. 503.

—— A monograph of the Phyllopod Crustacea of North America, with remarks on the order Phyllocarida. Pls. 1–38.

In Twelfth Rept. U. S. Geol. Survey Territories (Hayden), Washington, 1883, pt. 1, p. 295.

Hymenocaris, *Peltocaris*, *Ceratiocaris*, *Echinocaris*, *Discinocaris*, *Spathiocaris*, *Liegocaris*, *Aptychopsis*, *Dictyocaris*, *Dithyrocaris*, *Rachura*, *Argus*, *Estheria*, *Leaia*.

—— Types of Carboniferous *Xiphosura* new to North America.

In Am. Naturalist, vol. 19, 1885, p. 291.

Belinurus, *Euproops*, *Cyclus*, *Dipeltis* n. g.

—— The *Syncarida*, a group of Carboniferous Crustacea.

In Am. Naturalist, vol. 19, 1885, p. 700.

Acanthotelson.

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Packard, jr. (A. S.)—Continued.

—— On the *Gampsonychidæ*, an undescribed family of fossil *Schizopod* Crustacea.

In Am. Naturalist, vol. 19, 1885, p. 790; Mem. Nat. Acad. Sci., vol. 3, 1886, p. 129, pl. 3.

Palæocaris, Gampsonyx.

—— On the *Anthracoridæ*, a family of Carboniferous *Macrurous* decapod Crustacea allied to the *Eryonidæ*.

In Am. Naturalist, vol. 19, 1885, p. 880; Mem. Nat. Acad. Sci, vol. 3, 1886, p. 135, pl. 4.

Anthrapalæmon.

—— Discovery of the thoracic feet in a Carboniferous *Phyllocaridan*.

In Am. Philos. Soc., vol. 23, 1886, p. 380, plate.

Cryptozoe problematicus.

—— On the class *Podostomata*, a group embracing the Merostomata and Trilobites.

In Am. Naturalist, vol. 20, 1886, p. 1060.

Merostomata: *Xiphosura, Synziphosura, Eurypteridæ.*

—— On the Syncarida, a hitherto undescribed synthetic group of extinct Malacostracous Crustacea.

In Mem. Nat. Acad. Sci., vol. 3, pt. 2, 1886, p. 123, pls. 1, 2.

Acanthotelson.

—— On the Carboniferous Xiphosurous fauna of North America.

In Mem. Nat. Acad. Sci., vol. 3, pt. 2, 1886, p. 142, 8 figs., 3 pls.

Cyclus, Dipeltis, Prestwichia, Belinurus, Palæocaris, Anthrapalæmon, Protolimulus n. g., *Bunodes, Pseudoniscus, Exapinurus, Hemiaspis, Neolimulus.*

Page (David). On the *Pterygotus* and *Pterygotus* beds of Great Britain.

In Rept. 25th Meeting Brit. Assoc. Adv. Sci., 1855, Trans. Sec., p. 89.

The genus *Stylonurus* was proposed by Mr. David Page in his paper read before the Association, and the name published in his "Advance text-book of geology," 1856.

—— Further contributions to the palæontology of the Tilestones or Silurio-Devonian strata of Scotland.

In Rept. 28th Meeting Brit. Assoc. Adv. Sci., Trans. Sec., p. 104.

Beyrichia, Ceratiocaris, Himantopterus, Stylonurus spinipes, S. clavipes, Kampecaris, Eurypterus.

—— Advance text-book of geology. London, 1856.

Slimonia n. g., *Stylonurus* n. g., *Kampecaris, Himantopterus, Pterygotus, Parka.*

Page (David)—Continued.

In the second edition, 1859, Mr. David Page gives restorations of *Pterygotus anglicus, Himantopterus acuminatus, Stylonurus powriei, S. spinipes, Eurypterus clavipes, E. scouleri*, and *Limulus rotundatus.*

—— Note on the genus *Stylonurus* from the Old Red Sandstone of Forfarshire.

In Proc. Royal Phys. Soc. Edinburgh, session 1864–'65, p. 230.

Pander (C. H.) Beiträge zur Geognosie des russischen Reiches. St. Petersburgh, 1830; Leipzig, 1839, 31 pls.

Calymene, Asaphus, Illænus, Nileus, Amphion n. g., *Zethus* n. g.

Parkinson (James). Organic remains of a former world, an examination of the mineralized remains of the vegetable and animal antediluvian world generally termed extraneous fossils. London, 1808, 3 vols. Crustacea, vol. 3, letter 16*, pl. 17.

Calymene, Ogygia, Encrinurus, Phacops, Belinurus.

Payton. (—). Trilobites found in the Transition limestone at Dudley, from the collection of Mr. Payton, at Dudley. London, 1827, 2 pp., 2 pls.

Calymene blumenbachii and *Asaphus caudatus.*

Peach (B. N.) On some new Crustaceans from the Lower Carboniferous rocks of Eskdale and Liddesdale.

In Trans. Royal Soc. Edinburgh, vol. 30, pt. 1, 1880, p. 73, 4 pls.

Ceratiocaris, Anthrapalæmon, Palæocrangon, Palæocaris, Uronetes.

—— Further researches among the Crustacea and Arachnida of the Carboniferous rocks of the Scottish border.

In Trans. Royal Soc. Edinburgh, vol. 30, pt. 2, 1880, p. 511, 2 pls.

Prestwichia, Cyclus, Eurypterus, Glyptoscorpius n. g., *Acanthocaris* n. g., *Anthrapalæmon, Palæocrangon, Palæocaris, Pseudo-Galathea* n. g.

—— On the occurrence of *Pterygotus* and a *Limuloid* in the Caithness Flagstones, and on the nature and mode of formation of "Adam's plate."

In Proc. Royal Phys. Soc. Edinburgh, 1883, p. 343, plate.

Pterygotus dicki.

Phillips (John). On the occurrence of some minute fossil Crustaceans in Palæozoic rocks.

In Rept. 11th Meeting Brit. Assoc. Adv. Sci., 1841, Trans. Sec., p. 64.

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Phillips (John)—Continued.

—— Illustrations of the geology of Yorkshire. Pt. 2. The mountain limestone district. London, 1836, p. 239.

Asaphus (*Phillipsia*).

—— Figures and descriptions of the Palæozoic fossils of Cornwall, Devon, and West Somerset, observed in the course of the Ordnance Geological Survey of that district. London, 1841, 60 pls. Crustacea, p. 127.

Harpes, *Calymene* (*Ceraurus*, *Phacops*), *Homalonotus*, *Asaphus*, *Bronteus*.

—— The Malvern Hill compared with the Palæozoic district of Abberley, Woolhope, May Hill, Tortworth, and Usk.

In Mem. Geol. Survey Gt. Brit., vol. 2, pt. 1, London, 1848. Palæontological appendix to Prof. John Phillips's memoir on the "Malvern Hills compared with the Palæozoic district of Abberley," etc., by John Phillips and J. W. Salter. *Ibid.*, pp. 331–386, 30 pls.

For list of genera, see Salter (J. W.) and Phillips (John).

—— Manual of geology. Pt. 2. Ed. by Rob. Etheridge. 1885, pls. 1–12.

Paradoxides, *Olenus*, *Asaphus*, *Ogygia*, *Calymene*, *Trinucleus*, *Agnostus*, *Illænus*, *Lichas*, *Beyrichia*, *Stygina*, *Phacops*, *Cybele*, *Cheirurus*, *Remopleurides*, *Harpes*, *Ampyx*, *Acidaspis*, *Cyphoniscus*, *Æglina*, *Sphærexochus*, *Encrinurus*, *Cyphaspis*, *Proetus*, *Pterygotus*, *Bronteus*, *Homalonotus*, *Phillipsia*.

Pictet (F.-J.) Traité de paléontologie, ou histoire naturelle des animaux fossiles considérés dans leurs rapports zoologique et géologique. 4 vols and atlas. Paris, 1853–'57. Crustacea, vol. 2, 1854, p. 413.

The author arranges the families and genera as follows: Harpidæ: *Harpes*. Paradoxidæ: *Remopleurides*, *Paradoxides*, *Hydrocephalus*, *Sao*, *Arionellus*, *Ellipsocephalus*, *Olenus*, *Peltura*, *Triarthrus*, *Conocephalites*. Calymenidæ, 1st section, Proetidæ: *Proetus*, *Phillipsia*, *Cyphaspis*, *Arethusina*, *Harpes*; 2d section, Phacopidæ: *Phacops*, *Dalmania*; 3d section, Calymenidæ: *Calymene*, *Homalonotus*. Lichasidæ. *Lichas*. Trinucleidæ: *Trinucleus*, *Ampyx*, *Dionide*. Asaphidæ: *Asaphus*, *Symphysurus*, *Ogygia*. Ægilinidæ: *Æglina*. Illænidæ: *Illænus*, *Nileus*. Odontopleuridæ: *Acidaspis*, *Cheirurus*, *Placoparia*, *Sphærexochus*, *Staurocephalus*, *Deiphon*, *Zethus*, *Dindymene*. Amphionidæ: *Amphion*, *Cromus*, *Encrinurus*. Brontidæ: *Bronteus*. Agnostidæ: *Agnostus*. Phyllopodæ: *Apusiens*, *Dithyrocaris*, *Apus*, *Estheria*, Copepodæ: *Eurypterus*. Cyproidæ: *Cythere*, *Bairdia*, *Beyrichia*, *Leperditia*, *Cypris*. Cypridinæ: *Cyprella*, *Cypridella*. Xiphosuræ: *Limulus*, *Belinurus*, *Pterygotus*. Amphipodæ: *Gampsonyx*.

Pitt. See **Grote and Pitt.**

Plant (John). On the discovery of *Paradoxides davidis* at Tyddyngwladis, near Dolgelly, North Wales.

In Trans. Manchester Geol. Soc., vol. 5, 1866, p. 76.

Pohlman (Julius). On certain fossils of the Waterlime group near Buffalo.

In Bull. Buffalo Soc. Nat. Sci., vol. 4, 1881, p. 17, 7 figs.

Pterygotus bufaloensis, *Ceratiocaris grandis*.

—— Additional notes on the fauna of the Waterlime group.

In Bull. Buffalo Soc. Nat. Sci., vol. 4, 1882, p. 41, 2 pls.

Eurypterus giganteus, *Pterygotus globicaudatus*, *P. acuticaudatus*, *P. quadraticaudatus*, *P. macrophthalmus?*, *P. bufaloensis*.

—— Fossils from the Waterlime group near Buffalo, N. Y.

In Bull. Buffalo Soc. Nat. Sci., vol. 5, 1886, p. 17, pl. 3.

Pterygotus bufaloensis, *P. bilobus*, *Ceratiocaris acuminatus*, *Eusarcus*, *E. grandis*, *Eurypterus scorpionis* (the term *Eurypterus scorpiædes* was used by Henry Woodward for a species of this genus in 1868. See *Eurypterus pohlmani*).

Portlock (J. E.) Report on the geology of the county of Londonderry, and of parts of Tyrone and Fermanagh. Dublin, 1843, 28 pls., also maps and sections.

Harpes, *Remopleurides* n. g., *Proetus*, *Phillipsia* n. g., *Griffithides* n. g., *Phacops*, *Calymenes*, *Trinucleus*, *Ampyx*, *Nuttainia*, *Asaphus*, *Isotelus*, *Ogygia*, *Ceraurus*, *Amphion*, *Zethus*, *Brontes*, *Illænus*, *Dithyocaris* (Scouler) Portlock, *Limulus*.

Postlethwaite (J.) and **Goodchild** (J. G.) On some Trilobites from the Skiddaw slates.

In Proc. Geologist Assoc., vol. 9, No. 7, 1886, p. 455, pls. 6–9.

In this contribution the initials of each author designate the paragraphs written by him.

The following list is given of the Trilobite fauna of the Skiddaw slates:

Phacops nicholsoni Salter, *Cybele ovata* Etheridge, *Calymene brevicapitata?*, *Remopleurides* sp.?, *Olenus* sp.?, *Trinucleus gibbsii?*, *Ogygia selwyni*, *Ogygia* sp.?, *Barrandia falcata* P. & G., *Niobe doveri* Eth., *Eurymetopus cambrianus* n. g. and n. sp. P. & G., *E. harrisonii* P. & G., *Æglina? rediviva* Barr., *A. binodosa*, *A. obtusicauda* Hicks, *A.? caliginosa*, *Agnostus morei* Salter.

Prestwich (S.) On the geology of Coalbrook Dale.

In Trans. Geol. Soc. London, vol. 5, 1840, p. 413, map, 2 sections, 4 pls.

Belinurus.

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Quenstedt (F. A.) Beiträge zur Kenntniss der Trilobiten. Rücksicht auf ihre bestimmte Gliederzahl.

In Archiv für Naturgesch. (Wiegmann), vol. 1, Berlin, 1837, p. 337.

In this work Prof. F. A. Quenstedt divides the Trilobites into two groups: 1. Trilobites with faceted eyes; 2. Trilobites with non-faceted eyes. The genera are classified according to the number of segments in the thorax.

Rafinesque (C. S.) On the genera of fossil Trilobites or Glomerites of North America.

In Atlantic Jour. and Friend to Knowledge, vol. 1, 1832, p. 71.

Ramsay (A. C.) The geology of North Wales, with an appendix on the fossils; with plates by J. W. Salter.

In Mem. Geol. Survey Gt. Brit., vol. 3, 1866.

Dikelocephalus, Olenus, Parabolina, Conocoryphe, Angelina, Homalonotus, Lichas, Trinucleus, Dionide, Ampyx, Asaphus, Niobe, Æglina, Cheirurus, Encrinurus, Illænus, Agnostus, Psilocephalus, Beyrichia, Hymenocaris.

Rathbun (Richard). See **Hartt** (C. F.) and **Rathbun** (Richard).

Ratte (F.) Note on some Trilobites new to Australia.

In Proc. Linn. Soc. New South Wales, 2d series, vol. 1, 1886, p. 1067, 3 pls.

Lichas, Proetus, Acidaspis.

—— Note on some Trilobites new to Australia.

In Proc. Linn. Soc. New South Wales, 2d series, vol. 2, 1887, p. 95, 2 pls.

Lichas, Acidaspis, Staurocephalus.

Razoumowsky (*Comte* de). Quelques observations sur les Trilobites et leurs gisements.

In Annales Sci. Nat. Paris, vol. 8, 1826, p. 186.

Trilobites de Zarsko sílo.

Remete (A.) Kataloge der Geschiebesammlung. Berlin, 1885. (*)

Reuss (A. E.) Entomostraca and Foraminifera of the Zechstein of the Wetterau. Plate.

In Jahresbericht der wetterauischen Gesell. für die gesammte Naturk., 1854, p. 59 (Hanau).

—— Palæontologische Miscellen.

In Denkschriften k. Akad. Wiss. Wien, vol. 10, 1856, 7 pls.

Lepidoderma n. g., *Lepidoderma imhoffi.*

This genus is referred by H. Woodward to the genus *Eurypterus.*

Reuss (F.) Geognostische Bemerkungen auf einer Reise durch einen Theil des Pilsner Kreises.

In Sammlung naturhist. Aufsätze, vol. 4, 1794, p. 47.

Reuter (G.) Die *Beyrichien* der obersilurischen Diluvialgeschiebe Ostpreussens.

In Zeitschr. Deutsch geol. Gesell., Berlin, vol. 37, 1885, p. 621, pls. 25, 26.

Richter (R.) Beiträge zur Palæontologie Thüringens. Leipzig, 1848, 6 pls.

—— Aus dem thüringischen Zechstein.

In Zeitschr. Deutsch. geol. Gesell., Berlin, vol. 7, 1855, p. 526.

Cythere, Cytherella, Cythereis, Bairdia.

—— Aus dem thüringischen Schiefergebirge.

In Zeitschr. Deutsch. geol. Gesell., Berlin, vol. 15, 1863, p. 659, 2 pls.

Harpes, Proetus, Arethusina, Phyllaspis n. g., *Phacops, Acidaspis, Beyrichia.*

—— Aus dem thüringischen Schiefergebirge.

In Zeitschr. Deutsch. geol. Gesell., Berlin, vol. 17, 1865, p. 361, 2 pls.

Proetus expansus, P. plagiophthalmus, Cheirurus, Beyrichia klödeni, B. subcylindria.

—— Das thüringische Schiefergebirge.

In Zeitschr. Deutsch. geol. Gesell., Berlin, vol. 21, 1869, p. 341.

Proetus, Phacops, Dalmanites.

—— Devonische Entomostraceen in Thüringen.

In Zeitschr. Deutsch. geol. Gesell., Berlin, vol. 21, 1869, p. 757, pls. 20, 21.

Beyrichia, Cypridina, Cytherina.

Roberg (L.) Dissertatio academica de fluviatile Astaco, etc. Upsaliæ, 1715.

This work contains a plate with the figure of the pygidia of Trilobites and a fossil Crustacean. Fig. H is of a large pygidium of some species of *Asaphus.* Fig. J is a cast in stone of a smaller species of the same genus. The author remarks "that he found the specimens during an excursion along the shores of the Baltic Sea, in a red limestone." He has the merit of referring these fossils to the class Crustacea.

Roemer (F. A.) Versteinerungen der Hartzgebirge. Hannover, 1843, 12 pls. Crustacea, p. 37.

Brontes flabellifer, B. signatus, B.? glabratus, Calymene? jordoni, C. schusteri, C. subornatus, C. hydrocephala, Asaphus zinckeni, Paradoxides grotei, Homalonotus ahrendi, H. punctatus, H. gigas.

Roemer (Ferdinand). Beiträge zur geologischen Kenntniss des nordwestlichen Harzgebirges.

In Palæontographica, vols. 3, 5, and 13, 5 pts., Cassel, 1854–'66, 38 pls.

Conocephalus, Proetus, Cyphaspis, Phacops, Trimerocephalus, Homalonotus, Lichas, Bronteus, Acidaspis, Trochus, Cheirurus, Dithyrocaris, Cypridina, Harpes, Phillipsia.

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Roemer (Ferdinand)—Continued.

—— Das rheinische Uebergangsgebirge, eine palæontologisch-geognostische Darstellung. Hannover, 1844, pl. 2.

Phacops latifrons, *Pleuracanthus acimatus*, *P. punctatus*, *Gerastos lævigatus*.

—— Texas, mit besonderer Rücksicht auf deutsche Auswanderung und die physischen Verhältnisse des Landes, nach eigener Beobachtung geschildert. Mit einem naturwissenschaftlichen Anhange und einer topographisch-geognostischen Karte von Texas. Bonn, 1849.

In the list of fossils on p. 421 *Pterocephalia sancti sabæ* Roemer is mentioned.

—— Ueber ein bisher nicht beschriebenes Exemplar von *Eurypterus* aus devonischen Schichten des New York.

In Palæontographica, vol. 1, 1851, p. 190.

—— Die Kreidebildung von Texas. Bonn, 1852, 11 pls.

Pterocephalia sancti sabæ n. g. and sp.

—— Notiz über eine riesenhafte neue Art der Gattung *Leperditia* in silurischen Diluvial-Geschieben Ost-Preussen's.

In Zeitschr. Deutsch. geol. Gesell., Berlin, vol. 10, 1858, p. 356, 2 figs.

Leperditia baltica, *L. gigantea*.

—— Die Versteinerungen der silurischen Diluvial-Geschiebe von Gröningen in Holland.

In Neues Jahrbuch für Mineral., 1858, p. 257.

Proetus, *Encrinurus*, *Beyrichia*, *Cytherina*.

—— Die Silurische Fauna des westlichen Tennessee. Breslau, 1860, 5 pls.

Dalmania, *Calymene*, *Ceraurus*, *Sphærexochus*, *Bumastus*.

—— Palæo-lethæa. II. Theil: Kohlen-Periode (Silur-, Devon-, Kohlen- und Zechstein-Formation).

In Bronn's Lethæa geognostica, etc., Stuttgart, 1851-'56.

For list of genera, see Bronn (H. G.) and Roemer (F.) Lethæa geogn.

—— Bericht über eine geologische Reise nach Norwegen im Sommer 1859.

In Zeitschr. Deutsch. geol. Gesell., Berlin, vol. 11, 1860.

Dalmania, *Cryphæus*, *Asaphus*, *Illænus*, *Phacops*.

—— Die fossile Fauna der silurischen Diluvial-Geschiebe von Sadewitz bei Oels in Niederschlesien. Breslau, 1861, 8 pls.

Ceraurus, *Remopleurides*, *Isotelus*, *Asaphus*, *Illænus*, *Chasmops*, *Proetus*, *Calymene*, *Encrinurus*, *Lichas*.

Roemer (Ferdinand)—Continued.

—— Ueber die Diluvial-Geschiebe von nordischen Sedimentär-Gesteinen in den norddeutschen Ebene etc.

In Zeitschr. Deutsch. geol. Gesell., Berlin, vol. 14, 1862, p. 575.

Beyrichia.

—— Ueber eine marine Conchylien-Fauna im productiven Steinkohlengebirge Oberschlesiens.

In Zeitschr. Deutsch. geol. Gesell., Berlin, vol. 15, 1863, p. 567, pls. 14-16.

Griffithides mesotuberculata McCoy, *Phillipsia*.

—— Notiz über das Vorkommen von *Eurypterus scouleri* im niederschlesischen Steinkohlengebirge.

In Zeitschr. Deutsch. geol. Gesell., Berlin, vol. 25, 1873, p. 562, 1 fig.

—— Lethæa palæozoica. Stuttgart, 1880. Text and atlas.

—— Ueber die Gattung *Arthropleura* aus dem schlesischen Steinkohlengebirge.

In Sitzungsber. schles. Gesell. für vaterländ. Cultur, Breslau, Jahrg. 1880, p. 128.

—— Ueber eine Kohlenkalk-Fauna der Westküste von Sumatra. Cassel, 1880, 3 pls.

Phillipsia sumatrensis Roemer.

—— Ueber eine Art der Limuliden-Gattung *Belinurus* aus dem Steinkohlengebirge Oberschlesien's.

In Zeitschr. Deutsch. geol. Gesell., Berlin, vol. 35, 1883, p. 429, 2 figs.

—— Lethæa erratica, oder Aufzählung und Beschreibung der in den norddeutschen Ebene vorkommenden Diluvial Geschiebe nordischen Sedimentär-Gesteine. Berlin, 1885, 11 pls.

In this work many Trilobites and other Crustacea are mentioned, but only a few new species are figured.

Rogers (W. B.) Discovery of *Paradoxides* in the altered rocks of Massachusetts.

In Edinb. New Philos. Jour., vol. 4, 1856.

—— On the discovery of Cambrian fossils at Braintree, Mass.

In Proc. Boston Soc. Nat. Hist., vol. 5, 1854, p. 27 (continued on p. 40).

Paradoxides harlani Green.

—— *Paradoxides* near Boston.

In Edinb. New Philos. Jour., vol. 6, 1857, p. 314.

Rogers (Henry D.) The geology of Pennsylvania. A Government survey with a general view of the geology

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Rogers (Henry D.)—Continued.

of the United States, essays on the coal formation and its fossils, and a description of the coal fields of North America and Great Britain. 2 vols. Edinburgh, London, and Philadelphia, 1858. Atlas of plates and maps.

Organic remains of the Palæozoic strata of Pennsylvania, vol. 2, pp. 815–834.

Paradoxides, *Asaphus*, *Calymene*.

Notes on the *Beyrichia* and *Leperditia*, by T. Rupert Jones, vol. 2, p. 834, figs. 595–699.

Rominger (C.) Description of Primordial fossils from Mount Stephens, N. W. Territory of Canada.

In Proc. Acad. Nat. Sci. Phila., 1887, p. 12, 1 pl.

Ogygia, *Embolimus* n. g., *Menocephalus*, *Conocephalites*, *Bathyurus?*, *Agnostus*.

—— Dr. C. Rominger's rejoinder to Mr. C. D. Walcott.

In Am. Geologist, vol. 2, 1888, p. 356.

Rouault (Marie). Mémoire sur les Trilobites du département d'Ille-et-Vilaine.

In Bull. Soc. Géol. France, 2d series, vol. 4, 1846, p. 309.

Trinucleus, *Nileus*, *Prionocheilus* n. g., *Calymene*, *Phacops*, *Polyeres*, *Cheirurus*, *Trinucleus*.

—— Mémoire. 1. Sur la composition du test des Trilobites. 2. Sur les changements de formes dus à des causes accidentelles, ce qui a pu permettre de confondre des espèces différentes.

In Bull. Soc. Géol. France, vol. 6, 1848, p. 67, pls. 1–2.

Ogygia brongniarti, *O. edwardsi*, *Illænus desmaresti*, *Calymene arago*, *Trinucleus*.

—— Fossiles du terrain silurien, étage du schiste, ardoisier fosillifère, Crustacés, famille des Trilobites.

In Bull. Soc. Géol. France, vol. 8, 1851, p. 358.

Calymene salteri, *C. verneuili*, *Dalmannia vetillarti*, *D. incerta*, *Placoparia tournemini*, *Ogygia desmaresti*, *Homalonotus brongniarti*, *H. barrandei*, *H. hausmanni*, *H. legraverendi*, *Plæsiacomia kieneria*, *Proetus huhayi*, *P. michelini*, *Cyphaspis*, *Beyrichia*, *Leperditia* n. g., *L. britannica*, *Phacops*.

Safford (J. M.) Geology of Tennessee. Nashville, 1869, 7 pls. and map.

The author, in his catalogue of Trenton and Nashville fossils occurring in the Central Basin, p. 285, gives the names of *Dalmanites troosti* n. s. and *Encrinurus excedrinus* n. s., but without specific descriptions.

Sandberger (G.) and **Sandberger** (F.) Die Versteinerungen des rheinischen Schichten-System in Nassau. Wiesbaden, 1850–'56, atlas in folio, 39 pls.

Sandberger (G.) and **Sandberger** (F.)—Continued.

Harpes, *Cyphaspis*, *Trigonaspis* n. g., *Cylindraspis* n. g., *Phacops*, *Dalmanites*, *Homalonotus*, *Odontopleura*, *Cheirurus*, *Bronteus*, *Cyprindia*.

Salter (J. W.) On the structure of *Trinucleus*, with remarks on other species.

In Quart. Jour. Geol. Soc. London, vol. 3, 1847, p. 251, 4 figs.

—— Crustacea.

In Mem. Geol. Survey Gt. Britain, vol. 2, pt. 1, 1848, pp. 333–352, figure, pls. 5–8.

Olenus, *Proetus*, *Phacops*, *Dalmannia*, *Calymene*, *Lichas*, *Trinucleus*, *Ampyx*, *Ogygia*, *Illænus*, *Acidaspis*, *Cheirurus*, *Sphærexochus*, *Cybele*, *Agnostus*, *Beyrichia*.

—— and **Forbes** (Edward). Figures and descriptions illustrative of British organic remains. Decade 2.

In Mem. Geol. Survey United Kingdom London, 1849, 10 pls.

Paradoxides, *Olenus*, *Parabolina* n. g., *Phacops*, *Dalmannia*, *Portlockia*, *Cryphæus*, *Calymene*, *Ampyx*, *Brachampyx* n. g., *Asaphus*, *Ogygia*, *Illænus*, *Bumastus*.

The description of all the species, with the exception of *Ampyx nudus*, was made by J. W. Salter.

—— Description of *Pterygotus problematicus* Agass.

In Quart. Jour. Geol. Soc. London, vol. 8, 1852, p. 386, pl. 21.

Pterygotus, *Bellinurus*.

—— Appendix A to British Palæozoic fossils in the Geological Museum, University of Cambridge. London, 1852 (Sedgwick and McCoy).

Description of a few species from Wales and Westmoreland, referred to in the foregoing work by John William Salter, p. 645.

Phacops, *Calymene*, *Homalonotus*, *Lichas*, *Illænus*, *Cheirurus*, *Encrinurus*, *Cybele*, *Beyrichia*, *Cythere*, *Eurypterus*.

—— On the lowest fossiliferous beds of North Wales.

In Rept. 22d Meeting Brit. Assoc. Adv. Sci., 1852, Trans. of Sec., p. 56.

Hymenocaris n. g.

—— On a few genera of Irish Silurian fossils.

In Rept. 22d Meeting Brit. Assoc. Adv. Sci., 1852, Trans. of Sec., p. 59.

Stygina n. g., *Cyphonisous* n. g., *Remopleurides*, *Cyphaspis*, *Æglina*, *Acidaspis*.

—— Notes on the Trilobites.

Appendix C to an article by Senhor Carlos Ribeiro on the Carboniferous and Silurian formations of the neighborhood of Bussaco, in Portugal.

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Salter (J. W.)—Continued.

In Quart. Jour. Geol. Soc. London, vol. 9, 1853, p. 158, pl. 7.

Phacops, Calymene, Trinucleus, Ogygia, Illænus, Placoparia.

—— On Arctic Silurian fossils.

In Quart. Jour. Geol. Soc. London, vol. 9, 853, p. 312.

Proetus, Encrinurus, Leperditia.

—— Figures and descriptions illustrative of British organic remains. Decade 7.

In Mem. Geol. Survey United Kingdom, London, 1853, 10 pls.

The genera are arranged in this work in the following order: 1. *Phacops downingiæ*, section Acaste, *P. apiculatus, P. brongniarti, P. dalmanni, P. jamesii, P. alifrons, P. jukesii, P. conophthalmus;* section Odontochile (*Dalmannia*), *P. mucronatus, P. amphora.* 2. *Cheirurus bimucronatus*, section Crotalocephalus, *C. articulatus?;* section Cheirurus, *C. speciosus, C. gelasinosus, C. cancrurus, C. octolobatus;* section Actinopeltis, *C. clavifrons.* 3. *Sphærexochus mirus.* 4. *Encrinurus sexcostatus, E. punctatus, E. variolaris, E. multisegmentatus.* 5. *Cyphaspis megalops, C. pygmæus* 6. *Acidaspis jamesii, A. bispinosus, A. caractaci.* 7. *Trinucleus lloydii*, section 1, Trinucleus proper, *T. concentricus*, with four varieties, *T. thersites;* section 2, Tretaspis, *T. seticornis, T. fimbriatus, T. radiatus.* 8. *Remopleurides colbii, R. lateristinifer, R. dorsopinifer;* section Remopleurides, *R. platyceps, R. longicostatus, R. obtusus;* section 2, Caphyra, *R.* (*Caph.*) *radians.* 9. *Cyphoniscus socialis.* 10. *Æglina mirabilis, Æglina major.*

—— On some new Crustacea from the uppermost Silurian rocks, by J. W. Salter. With a note on the structure and affinities of Himantopterus, by T. H. Huxley.

In Quart. Jour. Geol. Soc. London, vol. 12, 1856, pl. 26, figs. 1-7.

Himantopterus n. g.

—— Description of the Crustaceans from the uppermost Silurian rocks near Lesmahago.

In London, Edinb., Dublin Philos Mag., vol. 11, 1856, p. 83.

Himantopterus.

—— On the great *Pterygotus* (Seraphim) of Scotland and other species.

In Rept. 26th Meeting Brit. Assoc. Adv. Sci., 1856, Trans. of Sec., p. 75.

—— On fossil remains in the Cambrian rocks of the Longmynd and North Wales.

In Quart. Jour. Geol. Soc. London, vol. 12, 1856, p. 246.

Palæopyge ramseayi, pl. 4, fig. 3, new species and genus.

Salter (J. W.)—Continued.

—— On two Silurian species of *Acidaspis* from Shropshire.

In Quart. Jour. Geol. Soc. London, vol. 13, 1857, p. 210, pl. 6.

—— On some new species of *Eurypterus*. With note on the distribution of the species.

In Quart. Jour. Geol. Soc. London, vol. 15, 1859, p. 229, pl. 10.

—— On the fossils of the Lingula flags or zone Primordiale *Paradoxides* and *Conocephalus* from North America.

In Quart. Jour. Geol. Soc. London, vol. 15, 1859, p. 551, 4 figs.

Paradoxides bennetti, Conocephalus antiquatus, Asaphus or *Olenus* sp.?

—— New Silurian Crustacea.

In Annals Mag. Nat. Hist., 3d series, London, vol. 5, 1860, p. 153, figures.

Ceratiocaris, Dictyocaris n. g., *Physocaris* n. g.

—— On the fossils from the High Andes, collected by David Forbes.

In Quart. Jour. Geol. Soc. London, vol. 17, 1861, p. 62, pls. 4, 5.

Proetus (*Cryphæus*) *pentlandi, Homalonotus linares, H.* sp.?, *Beyrichia forbesii, Phacops latifrons* Bronn.

—— On some of the higher Crustacea from the British Coal Measures.

In Quart. Jour. Geol. Soc. London, vol. 17, 1861, p. 528, figs. 1-8.

Anthrapalæmon n. g., *Palæocrangon* n. g.

Name changed to that of *Crangopsis*. See same journal, vol. 19, p. 80.

—— Crustacea in the Coal Measures.

In London, Edinb., Dublin Philos. Mag., vol. 22, 1861, p. 325.

Anthrapalæmon.

This is merely a notice of the article referred to in the Quart. Jour. Geol. Soc., vol. 17, 1861, p. 528.

—— Description of *Uroneotes* (*Gamponyx*) *socialis* in the Rev. T. Brown's paper, "Mountain limestone and Lower Carboniferous rocks of the Fifeshire coast." (*)

In Trans. Royal Soc. Edinb., vol. 22, pt. 2, 1861, p. 394.

—— A monograph of British Trilobites.

In Palæont. Soc. London, vol. 16, 1862, pp. 1-83, pls. 1-6, pt. 1.

Phacops, subgenera *Trimerocephalus* McCoy, *Phacops* Emm., *Acaste* Gold., *Chasmops* McCoy, *Odontochile* Corda, *Cryphæus* Green.

Cheirurus, subgenera *Crotalocephalus* Salter, *Cheirurus* Beyrich, *Eccoptochile* Corda, *Actinopeltis* Corda, *Sphærexochus* Beyrich.

Amphion Pander.

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Salter (J. W.)—Continued.

—— On some fossil Crustacea from the Coal Measures and Devonian rocks of New Brunswick, Nova Scotia, and Cape Breton.

In London, Edinb., Dublin Philos. Mag., 4th series, vol. 24, 1862, p. 166.

—— A monograph of British Trilobites. Pt. 2. Pp. 81–128, pls. 7–19.

In Palæont. Soc. London, vol. 17, 1863.

Calymene, *Homalonotus*, subgenera *Brongniartia* Salter (not *Brongniartia* Eaton), *Trimerus* Green, *Dipleura* Green, *Kænigia* Salter, *Burmeisteria* Salter; *Ogygia*, *Staurocephalus*, *Deiphon*, *Amphion*.

—— On some fossil Crustacea from the Coal Measures and Devonian rocks of British North America.

In Quart. Jour. Geol. Soc. London, vol. 19, 1863, p. 75, figs. 1–12.

Amphipeltis n. g., *Diplostylus* n. g., *Eurypterus*, *Palæocrangon*.

The author herein changes the name *Palæocrangon* Salter to that of *Crangopsis*.

—— On some species of *Eurypterus* and allied forms.

In Quart. Jour. Geol. Soc. London, vol. 19, 1863, p. 81, 8 wood-cuts.

Eurypterus scouleri, *E.* (*Arthropleura?*) *mammatus*, *E.?* (*Arthropleura*) *ferox*.

—— On Peltocaris, a new genus of Silurian Crustacea.

In Quart. Jour. Geol. Soc. London, vol. 19, 1863, p. 87.

Peltocaris n. g., *Hymenocaris*, *Ceratiocaris*, *Dictyocaris*, *Dithyrocaris*, *Arges*, *Apus*, *Nebalia*, *Estheria*, *Leperditia*, *Beyrichia*.

—— On some tracks of Lower Silurian Crustacea.

In Quart. Jour. Geol. Soc. London, vol. 19, 1863, p. 92, figures.

—— Note on the Skiddaw slate fossils.

In Quart. Jour. Geol. Soc. London, vol. 19, 1863, p. 135, figures.

Caryocaris n. g.

—— On the discovery of Paradoxides in Britain.

In Quart. Jour. Geol. Soc. London, vol. 19, 1863, p. 274.

Paradoxides davidis.

—— On a new Crustacean from Glasgow Coal Field.

In Quart. Jour. Geol. Soc. London, vol. 19, 1863, p. 519, figs. 1, 2.

Palæocarabus russellianus.

—— A monograph of British Trilobites. Pt. 3. Pp. 129–179, pls. 15–25.

In Palæont. Soc. London, vol. 18, for 1864 (London, 1866).

Salter (J. W.)—Continued.

Ogygia, subgenera *Barrandia*, and *Hemalopteon*; *Niobe*, *Asaphus*, subgenera *Ptychopyge*, *Basilicus*, *Megalaspis*, *Isotelus*, *Cryptonymus*, *Symphysurus*, *Brachyaspis*, and *Nileus*; *Stygina*, *Psilocephalus* n. g.

—— Figures and descriptions illustrative of British organic remains. Decade XI. Trilobites (chiefly Silurian).

In Mem. Geol. Survey United Kingdom, London, 1864, 19 pls.

Paradoxides, *Angelina*, *Olenus*, *O.* (*Leptoplastus*), *O.* (*Peltura*), *O.* (*Sphærophthalmus*), *O.* (*Parabolina*), *Conocoryphe*, *Phacops* (*Trimerocephalus*), *Salteria* n. g., *Stygina*, *Asaphus*, *Æglina*, *Staurocephalus*, *Agnostus*, *A.* (*Condylopyge*), *A.* (*Trinodus*), *A.* (*Phalacroma*).

The article on *Salteria primæva* n. g. et sp., pl. 6, was edited by P. Wyville Thomson.

—— On some fossils from the Lingula flags of Wales.

In Quart. Jour. Geol. Soc. London., vol. 20, 1864, p. 233, pl. 13.

Paradoxides, *Anopolenus* n. g., *Conocoryphe*, *Holocephalina* n. g., *Microdiscus*, *Agnostus*, *Leperditia*.

—— Note on the fossils from the Budleigh Sandstone Pebble bed.

In Quart. Jour. Geol. Soc. London, vol. 20, 1864, p. 286, pl. 15.

Phacops incertus, *Calymene tristani*, *Homalonotus brongniarti*, *Myocaris* n. g.

For detailed description of Myocaris, see Geol. Mag., vol. 1, London, 1864, p. 11, fig. 4.

—— On the new genus *Anopolenus*.

In Geol. Mag., vol. 1, London, 1864, p. 6.

Anopolenus n. g., *Myocaris*.

—— Catalogue of the Museum of Practical Geology of London. London, 1865.

—— and **Woodward** (Henry). Chart of fossil Crustacea, accompanied by a descriptive catalogue of all the genera and species figured. London, 1865, pls. 3 and 4.

Permian: *Prosopiniscus*, *Dalmanites? kabliktæ*, *Estheria*, *Kirkbya*, *Bairdia*, *Cytheridei*s, *Cythere*, *Limulus*.

Coal: *Palæocarabus*, *Pygocephalus*, *Uronectus* (*Gampsonyx*), *Diplostylus*, *Phillipsia*, *Estheria*, *Beyrichia*, *Kirkbya*, *Leperditia*, *Candona*, *Leaia*, *Arthropleura*, *Eurypterus*, *Limulus?* (*Belinurus*).

Mountain Limestone: *Palæocrangon*, *Brachymetopus*, *Griffithides*, *Phillipsia*, *Dithyrocaris*, *Cyclus*, *Estheria*, *Cythere*, *Cypridina*, *Cyprella*, *Cypridella*, *Entomoconchus*, *Beyrichia*, *Bairdia*, *Leperditia*, *Eurypterus*, *Limulus? trilobitoides*.

Devonian: *Amphipeltis*, *Gitocrangon*, *Campecaris*, *Proetus*, *Encrinurus*, *Bronteus*, *Phacops*, *Cyphaspis*, *Arges*, *Typhomiscus*, *Homalonotus*, *Harpes*, *Cypridina*, *Estheria*, *Leperditia*, *Ento-*

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Salter (J. W.)—Continued.

mis, Cypridina, Beyrichia, Bostrichopus, Eurypterus, Pterygotus.

Upper Silurian: *Bronteus, Illænus, Cyphaspis, Proetus, Aulacopleura, Phacops, Encrinurus, Acidaspis, Cheirurus, Homalonotus, Deiphon, Calymene, Harpes, Dictyocaris, Beyrichia, Ceratiocaris, Leperditia, Stylonurus, Pterygotus, Hemiaspis, Slimonia, Bunedes.*

Lower Silurian: *Asaphus, Stygina, Nileus, Illænus, Æglina, Ogygia, Agnostus, Niobe, Phacops, Trinucleus, Ampyx, Sphærexochus, Dionide, Ecoptochile, Placoparia, Lichas, Cybele, Acidaspis, Calymene, Staurocephalus, Remopleurides, Cyphoniscus, Atops, Triarthrus, Corynexochus, Centropleura, Monocephalus, Peltocaris, Beyrichia, Cytheropsis, Protichnites.*

Cambrian: *Agnostus, Sao, Anomocaris, Dolichometopus, Anpocaris, Solenopleura, Ellipsocephalus, Arionellus, Conocoryphe, Olenus, Acerocaris, Hydrocephalus, Paradoxides, Loncho-cephalus, Dikelocephalus, Palæopyge.*

See also Rept. 35th Meeting Brit. Assoc. Adv. Sci., 1865, Trans. of Sec., p. 79; Geol. Mag., vol. 2, London, 1865, p. 468.

—— and **Blanford** (H. F.) Palæontology of Nib, in the northern Himalayas. Calcutta, 1865.

—— On some additional fossils from the Lingula flags, with a note on the genus *Anopolenus*, by Henry Hicks.

In Quart. Jour. Geol. Soc. London, vol. 21, 1865, p. 476.

Anopolenus, Conocoryphe, Microdiscus, Holocephalina, Agnostus, Erinnys n. g.

—— On the fossils of North Wales.

In Mem. Geol. Survey Gt. Brit., vol. 3, London, 1866, p. 239, 37 pls.

Dikelocephalus, Olenus, Parabolina, Conocoryphe, Angelina, Homalonotus, Lichas, Trinucleus, Dionide, Ampyx, Asaphus, Niobe, Æglina, Cheirurus, Encrinurus, Illænus, Agnostus, Psilocephalus, Beyrichia, Hymenocaris.

—— A monograph of British Trilobites. Pt. 4. Pp. 177–216, pls. 25–30.

In Palæont. Soc., vol. 20, 1867.

Ogygia, Barrandia, Illænus, subgenera *Octillænus, Panderia, Dysplanus, Illænus, Ectillænus, Hydrolænus, Illænopsis*, and *Bumastus*. Family *Bronteidæ*.

—— A monograph of British Trilobites.

This work forms different parts of the Palæont. Soc. London, volumes for 1862–'67, as separately itemized in this connection.

—— On *Saccocaris major*.

In Rept. Proc. Geol. Polytech. Soc. West Riding of Yorkshire (for 1867), vol. 4, 1868, p. 588.

—— and **Hicks** (Henry). On some fossils from the Menevian group.

In Quart. Jour. Geol. Soc. London, vol. 25, 1869, p. 51, pls. 2, 3.

Salter (J. W.)—Continued.

Paradoxides, Plutonia n. g., *Conocoryphe.*

In a note on p. 52, Mr. J. W. Salter suggests the new generic name of *Plutonia*, but leaves the description for another article.

A species of this genus was afterwards described and figured in the same journal, vol. 27, 1871, p. 299, pl. 15, figs. 1–8, under the name of *Plutonia sedgwicki* Hicks. This large species has affinities with the genera *Paradoxides* and *Anopolenus* in the form of its glabella, but differs, according to Hicks, "in having the whole surface covered with coarse tubercles or spines." The term *Plutonia* is objectionable, inasmuch as it was used in 1864 for a genus of the Mollusca.

—— Catalogue of the collection of Cambrian and Silurian fossils contained in the Geological Museum of the University of Cambridge, 1873.

—— and **Etheridge** (R.) On the fossils of North Wales.

In Geology of North Wales, with an appendix on the fossils by J. W. Salter, revised and added to by R. Etheridge; Mem. Geol. Survey Gt. Brit., vol. 3, London, 1881, 2d ed., 622 pp., 113 illustrations, 2 geol. maps, 26 plates of fossils.

Paradoxides, Plutonia, Anopolenus, Dikelocephalus, Olenus, (Sphærophthalmus), Conocoryphe, Angelina, Arionellus, Phacops, Calymene, Homalonotus, Lichas, Trinucleus, Ampyx, Dionidæ, Æglina, Asaphus, Ogygia, Barrandia, Niobe, Illænus, Illænopsis, Cheirurus, Placoparia, Encrinurus, Cybele, Agnostus, Microdiscus, Carausia, Holocephalina, Nesuretus, Psilocephalus, Hymenocaris, Lingulocaris, Ceratiocaris, Entomis, Beyrichia, Leperditia.

—— Monograph of British Trilobites from the Cambrian, Silurian, and Devonian formations. Pt. 5.

Palæont. Soc. London, vol. 37, 1883, pp. 215, and index, 3 figs.

Illænus bowmanni?, I. crassicauda, I. (*Bumastus*) sp.?

—— See **Huxley** (T. H.) and **Salter** (J. W.). Also **Salter** (J. W.) and **Sharpe** (D.).

Sars (M.) Ueber einige neue oder unvollständig bekannte Trilobiten.

In Isis (oder Encycl. Zeitung), Oken, 1833, p. 33.

Scheuchzer (J. J.) Specimen lithologiæ Helvetia. Turici, 8vo, 1702. (*)

—— Meteorologia et Orytographia Helvetica, oder Beschreibung der Luftgeschichten, Steinen, Metallen, etc. Turici, 1718. (*)

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Schlotheim (E. Fr. von). Beschreibung einer seltenen Trilobiten-Art.

In Taschenbuch für gesam. Mineral., Leonhard, 1810, pl. 1, figs. 1-6.

Trilobiten cornigerus Schloth.

—— Nachträge zur Petrefactenkunde. II. Gotha, 1823, pl. 22.

1. *Trilobites blumenbachii*, 2. *T. tristani*, 3. *T. variolatus*, 4. *T. macrophthalmus*, 5. *T. sulzeri*, 6. *T. hoffi*, 7. *T. cornigerus*, 8. *T. de buchii*. 9. *T. hausmani*, 10. *T. schrost*, 11. *T. caudatus*, 12. *T. laticauda*, 13. *T. guettardi*, 14. *T. desmarestii*, 15. *T. tessini*, 16. *T. spinulosus*, 17. *T. scarabodes*, 18. *T. gibbosus*, 19. *T. laciniatus*, 20. *T. sphærocephalus*, 21. *T. pisiformis*, 22. *T. granulatus*, 23. *T. punctatus*, 24. *T. mucronatus*, 25. *T. bucephalus*, 26. *T. crassicauda*, 27. *T. tentaculatus*, 28. *T. problematicus*, 29. *T. bitumenosus*.

—— Beschreibung einiger abgebildeten Arten von Echinosphæriten und Trilobiten. (*)

In Isis (oder Encycl. Zeitung), Oken, 1826, p. 309, pl. 1, figs. 8, 9; also Féruss., Bull., 1827, vol. 12, p. 406.

Tril. esmarcki, *T. granum* (*Agnostus*).

Schmid (E. E.) Die kleineren organischen Formen des Zechsteinkalkes von Selters in der Wetterau.

In Neues Jahrbuch für Mineral., 1867, p. 576, plate.

Cythere.

Schmidt (Fr.) Untersuchungen über die silurische Formation von Ehstland, Nord-Livland und Oesel.

In Archiv Naturk. Liv-, Ehst- u. Kurl., Dorpat, vol. 2, 1858-'59, pp. 443, 445, 448, 453, 461, 463.

—— Miscellanæ Silurica. I. Ueber die russischen silurischen Leperditien mit Hinzuziehung einiger Arten aus den Nachbarländern.

In Mém. Acad. Imp. Sci. St.-Pétersbourg, vol. 21, No. 2, 1873, 1 pl.

Leperditia, *Isochilina*.

—— Einige Bemerkungen über die podolisch-galizische Silurformation und deren Petrefacten. St. Petersburg, 1875, 1 pl.

Prostus, *Cyphaspis*, *Phacops*, *Calymene*, *Encrinurus*, *Sphærexochus*, *Illænus* (*Bumastus*), *Leperditia*, *Eurypterus*, *Pterygotus*.

—— Revision der ost-baltischen silurischen Trilobiten, nebst geognostischer Uebersicht des ost-baltischen Silurgebiets.

In Mém. Acad. Imp. Sci. St.-Pétersbourg, vol. 26, No. 1, 1881, 16 pls.

Phacopidæ, genera, *Phacops*. *Acaste*, *Pterygometopus* n. g., *Chasmops*. Cheiruridæ, genera, *Cheirurus*, *Cyrtometopus*, *Sphærexochus*, *Pseudosphærexochus* n. g., *Nieszkowskia* n. g., *Amphion*, *Diaphanometopus* n. g., Encrinuridæ *Cybele*, *Encrinurus*.

—— and Jones (T. Rupert). On some Silurian Leperditia.

In Annals Nat. Hist., 4th series, vol. 9, London, 1882, p. 168.

—— Miscellanæ Silurica. III. 1. Nachtrag zur Monographie der russischen silurischen Leperditien. 2. Die Crustaceenfauna der Eurypterenschichten von Rootziküll auf Oesel.

In Mém. Acad. Imp. Sci. St.-Pétersbourg, vol. 31, No. 5, 1883, 9 pls.

Leperditia, *Bunodes*, *Pseudoniscus*, *Eurypterus*, *Pterygotus*, *Ceratocaris*.

—— and Jones (T. Rupert). See Jones (T. Rupert) and Schmidt (Fr.).

—— Ueber einige neue ostsibirische Trilobiten und verwandte Thierformen.

In Bull. Acad. Sci. Imp. St.-Pétersbourg, vol. 30, No. 4, 1886, p. 502.

Agnostus, *Phacops*, *Prostus*, *Cyphaspis*, *Eurypterus*.

Schrenk (G. A.) Uebersicht des obern-silurischen Schichten-Systems Liv- und Ehstlands, etc.

In Archiv Naturk. Liv-, Ehst- u. Kurl., Dorpat, vol. 1854, pp. 35 and 86.

Leperditia.

Scouler (John). Description of a fossil crustaceous animal. (*)

In Edinb. Jour. Nat. Geogr. Sci., vol. 3, 1831, p. 352, pl. 10.

The author describes in this article, under the new generic name of *Eidothea*, certain fragments of an *Eurypterus*.

—— Account of some fossil Crustacea which occur in the coal formation (*Argas*).

In Record of Geol. Sci. (Thomson's), vol. 1, 1835, p. 136.

According to Capt. J. E. Portlock (Rept. Geol. Londonderry, etc., 1843, p. 313), "Dr. John Scouler first noticed this remarkable Crustacean found by him in the Carboniferous strata of Paisley; and depending as a principal character on the lateral caudal appendages, he pointed out its analogy to the genera *Cyclops* and *Apus*; and again, at the meeting of the British Association at Glasgow, he described two species, one of which, *Argas tricornis*, in all probability depends on an illusive appearance produced by the overlapping of the crust of different individuals. * * * Dr. John Scouler having subsequently altered his view of the affinities of the genus, he now considers it a bi-valved Crustacean, distinguished by not being able to retract the tail within the shell, and hence has named it *Dithy-*

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Scouler (John)—Continued.

rocaris, or bivalved shrimp, abandoning the original name as one already pre-occupied."

The Rept. 10th Meeting Brit. Assoc. Adv. Sci., 1840, held at Glasgow, does not contain in the index Dr. Scouler's name or that of the genus *Argas* or *Dithyrocaris*. In the 5th Rept. of the "Committee on the Fossil *Phyllopoda* of the Palæozoic Rocks," 1887, the genus *Dithyrocaris* Scouler is quoted on the authority of Captain Portlock as follows: "*Dithyrocaris* Scouler in Portlock's Geol. Report, Londonderry, etc., 1843," p. 313.

Scudder (Samuel H.) *Rhachura*, a new genus of fossil Crustacea.

In Proc. Boston Soc. Nat. Hist., vol. 19, 1878, p. 296, pl. 9, figs. 3, 3 a.

In the 5th Rept. to the Brit. Assoc. Adv. Sci., 1887, on the fossil *Phyllopoda* by the committee, consisting of Mr. R. Etheridge, Dr. H. Woodward, and Prof. T. Rupert Jones this new genus of S. H. Scudder is referred to as probably of that of *Dithyrocaris* Scouler, 1843.

Shaler (N. S.) and **Foerste** (A. F.) Preliminary description of North Attleborough fossils.

In Bull. Mus. Comp. Zoöl. Harvard Coll., vol. 16, No. 2, 1888, Geol. Series, vol. 2, 1888, p. 27, 2 pls.

Paradoxides, *Ptychoparia*, *Microdiscus*.

Sharpe (Daniel). On the geology of the neighborhood of Oporto, including the Silurian, coal, and slates of Vallongo.

In Quart. Jour. Geol. Soc. London, vol. 5, 1849, p. 142, pl. 6.

Isotelus powissii Port., *Illænus lusitanicus* Sharpe.

—— Description of the new species of Zoophyta and Mollusca. Appendix B to an article on the Carboniferous and Silurian formations of the neighborhood of Bussaco, in Portugal, by C. Ribeiro.

In Quart. Jour. Geol. Soc. London, vol. 9, 1853, p. 146.

Dithyrocaris? longicauda Sharpe.

Shumard (B. F.) Palæontology. Crustacea.

In 1st and 2d Ann. Repts. of the Geol. Survey of Missouri (Swallow), 1855, pt. 2, p. 195, pl. B.

Proetus, *Cyphaspis*, *Phillipsia*, *Dalmania*, *Calymene*, *Acidaspis*, *Encrinurus*, *Cythere*.

—— Notice of new fossils from the Permian strata of New Mexico and Texas, collected by Dr. George G. Shumard, geologist of the U. S. Government expedition for obtaining water by means of artesian wells along the 32d parallel,

Shumard (B. F.)—Continued.

under the direction of Capt. John Pope, U. S. Corps of Top. Eng.

Trans. Acad. Sci. St. Louis, vol. 1, 1858, p. 200.

Phillipsia perannulata, pl. 11, fig. 10.

—— The Primordial zone of Texas, with descriptions of new fossils.

In Am. Jour. Sci., 2d series, vol. 32, 1861, p. 213.

Dikelocephalus, *Conocephalites*, *Arionellus*, *Agnostus*.

—— Notice of some new and imperfectly known fossils from the Primordial zone (Potsdam sandstone and calciferous sand group) of Wisconsin and Missouri.

In Trans. Acad. Sci. St. Louis, vol. 2, 1863, p. 101.

Dikelocephalus, *Arionellus*, *Conocephalites*, *Agnostus*.

—— Descriptions of new Palæozoic fossils.

In Trans. Acad. Sci. St. Louis, vol. 2, 1863, p. 108.

Proetus proutii.

Sjogren (A.) Anteckningar om Öland, ett bidrag till Sveriges geologi.

In Öfversigt K. Vet.-Akad. Förhandl. Stockholm, vol. 8, 1851, No. 2, p. 36.

Enumerates species of the following genera: *Remopleurides*, *Paradoxides*, *Ellipsocephalus*, *Olenus*, *Phacops*, *Calymene*, *Homalonotus*, *Lichas*, *Ampyx*, *Cheirurus*, *Asaphus*, *Illænus*, *Nileus*, *Battus*, *Cytherina*.

—— Om några försteningar i Ölands Kambriska lager.

In Geol. Föreningens Stockholm Förhandl., vol. 1, No. 5, 1871, 1 pl.

Paradoxides, *Ellipsocephalus*, *Conocoryphe*, *Agnostus*.

Sowerby (J. D. C.) Description of *Homalonotus knighti* in Adam Sedgwick and R. I. Murchison's article on the older formation on the right bank of the Rhine, etc.

In Trans. Geol. Soc. London, 2d series, vol. 6, 1842, p. 275, figure, pl. 38, fig. 17.

Stainer (X.) Note sur un Trilobite nouveau.

In Annales Soc. Géol. Belgique; Mémoires, vol. 14, 1887.

Dechenella.

Steinhart (E. T. G.) Die bis jetzt in preuss. Geschieben gefundenen Trilobiten.

In Beiträge zur Natur. Preuss., herausgegeben von der phys.-ökonomischen Gesell., Königsberg, 1874.

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Steinhart (E. T. G.)—Continued.

Harpes, Proetus, Cyphaspis, Phacops, Chamops, Calymene, Dalmania, Licha, Ampyx, Asaphus, A. (Basilicus), Illænus, Nileus, Bumastus, Acidaspis, Ceraurus, Sphærexochus, Zethus, Encrinurus, Agnostus.

Steininger (Jean). Observations sur les fossiles du calcaire intermédiaire de l'Eifel.

In Mém. Soc. Géol. France, vol. 1, 1831, p. 331, pl. 21.

Calymene brongniarti, C. latreilii, C. schlotheimii, C. tristani, Proetus n. g., *P. cuvieri, Olenus punctatus, Asaphus mucronati, A. laticauda.*

Sternberg (Kasper *Graf* von). Uebersicht der in Böhmen dermalen bekannten Trilobiten.

In Verhandl. mineral. Gesell. vaterländisch. Mus. Böhm., 1825, p. 69, pls. 2, 3; Isis (oder Encycl. Zeitung), Oken, vol. 7, 1827, p. 627.

Trilobites macrophthalmus, T. hausmanni, T. sulzeri, T. hoffi, T. tessini.

—— Ueber die Gliederung und die Füsse der Trilobiten.

In Isis (oder Encycl. Zeitung), Oken, 1830, pp. 516, 563, pl. 5, figs. 1-3.

—— Ueber böhmische Trilobiten.

In Verhandl. mineral. Gesell. vaterländisch. Mus. Böhm., 1833, p. 17.

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—— Description of a new Crustacean from the Upper Silurian of Georgia, with remarks on *Calymene clintoni.*

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—— Description of a new Crustacean from the Clinton group of Georgia, with remarks upon others. New York City, 1886, 5 pp., 4 figs.

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This work was published and distributed in 1818 as a separate article, in advance of the Nova Acta Reg. Soc. Sci., vol. 8, 1821.

—— Petrificata telluris Suecana examinata a Georgio Wahlenberg.

In Nova Acta Reg. Soc. Sci., Upsal., vol. 8, 1821, pp. 1-116, pls. 1-4.

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—— Additamenta quædam ad petrificata telluris Suecana.

In Nova Acta Reg. Soc. Sci., Upsal., vol. 8, 1821, pp. 293-296, pl. 7.

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Entomostracites crassicauda, pl. 7, fig. 5, has been referred by G. Holm. (De Svenska Arterna Trilobitslägetet *Illænus*, 1882, p. 55) to *Illænus esmarkii* Schlotheim.

Walch (J. E. T.) Des Trilobites dans le règne des pétrifications, ou de la conque ridée à trois lobes (concha triloba rugosa). Recueil des monumens des catastrophes que le globe de la terre a essuiées, contenant des pétrifications. (Knorr, G. W.) Vol. 3. Nuremberg, 1775, p. 105.

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See also vol. 2, 1768, section 1, p. 81; vol. 3, 1775, pp. 184, 185, 186, 193; suppl. pls. 8, 9 a, 9 b, 9 c, 9 e, 9 f. German and French editions.

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Walcott (C. D.) Description of a new species of Trilobite [from Trenton Falls, New York.]

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—— New species of Trilobite from the Trenton limestone at Trenton Falls, N. Y..

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—— Notes on *Ceraurus pleurexanthemus* Green.

In Annals Lyceum Nat. Hist., New York, vol. 11, 1876, p. 155, pl. 11.

—— Preliminary notice of the discovery of the remains of the natatory and branchial appendages of Trilobites.

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Arionellus, *Dalmanites*, *Asaphus*, *Acidaspis*, *Ceraurus*, *Encrinurus*, *Illænus*.

—— The Utica slate and related formations of the same geological horizon.

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—— Description of new species of fossils from the Carboniferous formation.

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—— The Trilobite, new and old evidence relating to its organization.

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—— Description of a new genus of the order *Eurypterus* from the Utica slate.

In Am. Jour. Sci., 3d series, vol. 23, 1882, p. 213, figures.

Echinognathus n. g.

—— Description of new species of fossils from the Trenton group, New York.

In 35th Rept. New York State Cab. Nat. Hist., 1883, p. 206, 1 pl.

Beyrichia, *Leperditia* (*Isochilina*).

Author's edition, October 15, 1883, 8 pp., 1 pl.

—— Injury sustained by the eye of a Trilobite at the time of moulting of the shell.

In Annals Nat. Hist., 5th series, vol. 13, London, 1884, p. 69.

—— On the locomotory appendages of Trilobites.

In Science, vol. 3, 1884, p. 279, 3 figs.

Asaphus megistos, *Calymene senaria*.

—— Palæontology of the Eureka district.

In Mon. U. S. Geol. Survey, vol. 8, 1884, 24 pls.

Dicellocephalus, *Olenellus*, *Ptychoparia*, *P.* (*Solenopleura*), *P.* (*Pterocephalus*), *Anomocare*, *Bathyurus*, *Chariocephalus*, *Ptychaspis*, *Agraulos*, *Proetus*, *Cyphaspis*, *Arethusina*, *Phillipsia*, *Griffithides*, *Phacops*, *Dalmanites*, *Trinucleus*, *Asaphus*, *Symphysurus*, *Ogygia?*, *Barrandia?*, *Illænurus*, *Ceraurus*, *Amphion*, *Illænus*, *Agnostus*, *Leperditia*, *Beyrichia*, *Primitia*, *Plumulites*.

—— On the Cambrian faunas of North America. Preliminary studies.

In Bull. U. S. Geol. Survey, No. 10, 1884, 10 pls.

Paradoxides, *Conocoryphe*, *Harttia* n. g., *Ptychoparia*, *Agnostus*, *Microdiscus*, *Agraulos*, *Protocaris* n. g.

—— Palæozoic notes: New genus of Cambrian Trilobites, *Mesonacis*.

In Am. Jour. Sci., 3d series, vol. 29, 1885, p. 328, figures.

Describes a new genus, *Mesonacis*, and substitutes the generic name *Bailiella* of Matthew for the subgenus *Salteria*, proposed by him (Bull. U. S. Geol. Survey, No. 10, 1884).

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—— Second contribution to the studies on the Cambrian fauna of North America.

In Bull. U. S. Geol. Survey, No. 30, 1886.

Figures and descriptions of species of the following genera are given, viz: *Paradoxides*, *Bathynotus*, *Mesonacis*, *Olenellus*, *Olenoides*, *Oryctocephalus* n. g, *Ptychoparia*, *Solenopleura*, *Anomocare*, *Crepicephalus*, *Dorypyge*, *Asaphiscus*, *Bathyuriscus*, *Agnostus*, *Microdiscus*, *Protypus* n. g., *Protocaris*, *Leperditia*.

—— Fauna of the upper Taconic of Emmons, in Washington County, New York, with one plate.

In Am. Jour. Sci., 3d series, vol. 34, 1887, p. 187.

Solenopleura?, *Ptychoparia?*, *Microdiscus*, *Olenoides*, *Conocoryphe*, *Aristozoe*, *Leperditia*.

—— Cambrian fossils from Mount Stephens, North West Territory of Canada.

Am. Jour. Sci., 3d series, vol. 36, 1888, p. 161.

Ptychoparia, *Agnostus*, *Bathyuriscus*, *Olenoides*, *Zacanthoides* n. g.

—— Stratigraphic position of the Olenellus fauna in North America and Europe.

Am. Jour. Sci., 3d series, vol. 37, 1889, p. 374.

Leperditia, *Aristozoa*, *Protocaris*, *Agnostus*, *Microdiscus*, *Olenellus*, *Paradoxides*, *Olenoides*, *Zacanthoides*, *Bathynotus*, *Avalonia* n. g., *Conocoryphe*, *Ptychoparia*, *Agraulos*, *Crepicephalus*, *Oryctocephalus*, *Anomocare*, *Protypus*, *Solenopleura*.

Waldschmidt (E.) Ueber die devonischen Schichten der Gegend von Wildungen.

In Zeitschr. Deutsch. geol. Gesell., vol. 37, 1885, p. 906, pls. 37–40.

Phacops, *Bronteus*, *Cypridina*.

Warder (John A.) New Trilobites.

In Am. Jour. Sci., 1st series, vol. 34, 1838, p. 377.

Ceratocephala n. g.

This article on the new genus *Ceratocephala* was read before the Western Academy of Science, May 25, 1838.

Washburn (W. T.) The geology of the Bosphorus.

In Am. Jour. Sci., 3d series, vol. 6, 1873, p. 186.

Not descriptive; contains important notes on fossil Crustacea.

Weitenweber (W. R.) Systematisches Verzeichniss der böhmischen Trilobiten in der Sammlung des Dr. Zeidler.

In Lotos, vol. 7, 1847, pp. 5–42.

Wetherby (A. G.) Description of a new family and genus of Lower Silurian Crustacea.

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Wetherby (A. G.)—Continued.

In Jour. Cincinnati Soc. Nat. Hist., vol. 1, 1878–'79, p. 162, figure, vol. 2, pl. 7, figs. 1, 1 a–g.

Enoploura balanoides.

—— Description of new fossils from the Lower Silurian and Subcarboniferous rocks of Ohio and Kentucky.

In Jour. Cincinnati Soc. Nat. Hist., vol. 4, 1881, p. 77.

Proetus, Isochilina.

White (C. A.) and **St. John** (O. H.) Preliminary notice of new genera and species of fossils. Iowa City, May 8, 1867, 3 pp.

Beyrichia lithofactor, B. lithofactor var. *velata, Cythere simplex.*

Of this small pamphlet only fifty copies were published by the Iowa State Geological Survey. Republished in Trans. Chicago Acad. Sci., vol. 1, 1867.

—— —— Description of new subcarboniferous and Coal-Measure fossils collected upon the geological survey of Iowa, together with a notice of new generic characters observed in two species of Brachiopods.

In Trans. Chicago Acad. Sci., vol. 1, pt. 1, 1867, p. 115, 2 figs.

Beyrichia petrifactor, B. petrifactor var. *velata, B. fœtoidea, Cythere simplex.*

In this article the authors give the new names of *Beyrichia petrifactor* to the species described in the preliminary notice as *B. lithofactor*, and also change the name of *B. lithofactor* var. *velata* to that of *Beyrichia petrifactor* var. *velata.*

—— Preliminary report upon invertebrate fossils collected by the expeditions of 1871, 1872, and 1873, with descriptions of new species.

In Geog. and Geol. Expl. Surveys West 100th Meridian, Washington, 1874.

Olenellus, Dicellocephalus, Megalaspis, Agnostus, Leperditia.

—— Report upon the invertebrate fossils collected in portions of Nevada, Utah, Colorado, New Mexico, and Arizona, by parties of the expeditions of 1871, 1872, 1873, and 1874.

In Geographical Surveys West 100th Meridian, Palæontology, vol. 4, 1877, pt. 1, pp. 1–219, pls. 1–21.

Olenellus, Dicellocephalus, Asaphiscus, Conocoryphe (*Ptychoparia*), *Megalaspis, Agnostus, Leperditia.*

—— Palæontology: Fossils of the Indiana rocks.

In 2d Ann. Rept. Dept. Statistics and Geology, Indiana, 1880, pp. 471–522, pls. 1–11.

White (C. A.) and **St. John** (O. H.)—Continued.

Calymene senaria, Cyphaspis christyi, Phillipsia bufo.

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In Proc. Nat. Hist. Soc. Glasgow, vol. 1, pt. 2, 1868, p. 171; also in Proc. Royal Phys. Soc. Edinburgh, vol. 4, 1878.

Solenocaris n. g. (not *Solenocaris* Meek.).

Zenker (J. C.) Beiträge zur Naturgeschichte der Urwelt. Organische Reste

Zenker (J. C.)—Continued.

(Petrefacten) aus der Altenburger Braunkohlen-Formation, dem Blankenburger Quadersandstein, jenaischen bunten Sandstein und böhmischen Uebergangsgebirge, mit 6 illuminirten Kupfertafeln. Jena, 1833.

Olenus longicaudatus, O. pyramidalis, O. latus, Otarion n. g., *O. difractum, O.? squarrosum, Conocephalus* n. g., *C. costatus, Ellipsocephalus* n. g., *E. ambiguus.*

The genus *Otarion* was made up from the head of *Cyphaspis burmeisteri* Barr., connected with the pygidium of *Oromus beamonti* Barr. The second species, described as *Otarion? squarrosum*, is referred by Joachim Barrande to *Cheirurus quenstadi.*

J. C. Zenker uses two generic names for his new genus *Conocephalus*, the first on p. 48 in describing the genus and the second in his description of plate 5, where he calls it *Trigonocephalus.*

Both these generic terms had been used in natural history for other genera, the first by Thurnburg in 1812 for a genus of the Orthoptera, and the second by Oppel in 1811 for the Reptiles.

The typical species described as *Conocephalus costatus* on p. 49, and also in the explanation of pl. 5, figs. G–K, p. 51, and as *Trigonocephalus costatus* in the description of pl. 5, given on p. 51, has been referred by Joachim Barrande to an amended genus, *Conocephalites* (Zenker) Barr., and the species to the older name of *sulzeri.* The other new genus, *Ellipsocephalus*, has been used by all subsequent authors.

Zeno (Franz). Von Seeversteinerungen und Fossilien, welche bei Prag zu finden sind.

In Neue phys. Belustigungen, etc., vol. 1, 1770, p. 65. Continued same vol., p. 362, pl. 1, fig. 1.

Under the names of *Cacada* or *Käfermuschel* Franz Zeno describes the pygidium of *Dalmanites hausmanni* and the head of *Phacops latifrons.*

Zittel (Karl A.) Handbuch der Palæontologie. Vol. 2. München und Leipzig, 1881–'85, p. 525.

Zippe (F. X.) See **Sternberg** (Kasper *Graf* von).

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PART II.

CATALOGUE OF TRILOBITES.

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PART II.

A SYSTEMATIC CATALOGUE OF AMERICAN PALEOZOIC CRUSTACEA. TRILOBITA.

First series, with grooved pleuræ.

Family.	Genera.	Reference.
Harpedidæ	Harpes Goldfuss, 1839	Nova Acta Physico-Med., vol. 19, p. 358. Type, *Harpes macrocephalus* Gold., *Harpes ungula* Sternb. Barrande, Syst. Sil. Bohême, vol. 1, p. 347, pls. 3–9.
Remopleuridæ.	Remopleurides Portlock, 1843.....	Geol. Rept. Londonderry, etc., p. 254. Type, *Remopleurides colbii* Portlock.
Paradoxidæ....	Paradoxides Brongniart, 1822.....	Hist. Crust. Foss., p. 30. Type, *Paradoxides tessini* Brong.
	Anopolenus Salter, 1864	Geol. Soc. London Jour., vol. 20, p. 236. Type, *Anopolenus henrici* Salter.
	Bathynotus Hall, 1860	Thirteenth Rept. New York State Cab. Nat. Hist., p. 117. Type, *Bathynotus holopyga* Hall.
	Dicellocephalus Owen, 1852.....	Rept. Geol. Survey Wisconsin, Iowa, and Minnesota, p. 573. Type, *Dikelocephalus minnesotensis* Owen.
	Mesonacis Walcott, 1884.....	Am. Jour. Sci., 3d series, vol. 29, p. 329. Type, *Olenus vermontana* Hall.
	Dolichometopus Angelin, 1854....	Palæont. Scand., p. 72. Type, *Dolichometopu svecicus;* Ang. Palæont. Scand., p. 73, pl. 37, fig. 9.
	Hydrocephalus Barrande, 1846....	Notice Prélim. Syst. Sil. Bohême, p. 18. Type, *Hydrocephalus carens* Barr. Notice Prélim. Syst. Sil. Bohême, p. 19.
	Olenellus Hall, 1861	Fifteenth Rept. New York State Cab. Nat. Hist., p. 114. Type, *Olenellus thompsoni* Hall. Twelfth Rept. New York State Cab. Nat. Hist., p. 59, figure.
	Olenus Dalman, 1826.....	Palæad., p. 56. Type, *Olenus gibbosus* Wahlenburg.
	Zacantholdes Walcott, 1887.....	Am. Jour. Sci., 3d series, vol. 36, p. 165. Type, *Olenoides spinosus* Walcott.
	Parabolina Salter, 1849.....	Mem. Geol. Survey United Kingdom, decade 2. Type, *Olenus spinulosa* Wahl.
	Peltura Milne-Edwards, 1840	Hist. Nat. Crust., vol. 3, p. 344. Type, *Olenus scarabæoides* Wahl.
	Cyclognathus Linnarsson, 1875 ...	Geol. Föreningens Stockholm Förhandl., vol. 2, No. 12, p. 500. Type, *Cyclognathus micropygus* Linnarsson.

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First series, with grooved pleuræ—Continued.

Family.	Genera.	Reference.
Paradoxides ...	Triarthrus Green, 1832	Mon. Trilobites North America, p. 87. Type, *Triarthrus beckii* Green.
	Leptoplastus Angelin, 1854	Palæont. Scand., p. 46. Type, *Leptoplastus stenotus* Angelin.
	Subgenera:	
	1. Sphærophthalmus Angelin, 1854.	Palæont. Scand., p. 49. Type, *Sphærophthalmus flagellifer* Ang.
	2. Ctenopyge Linnarsson, 1880.	Geol. Föreningens Stockholm Förhandl., vol. 5, p. 145. Type, *Olenus* (*Sphærophthalmus*) *pecten* Salter.
	Bœckia Brögger, 1882	Die silurischen Etagen 2 und 3, p. 122. Type, *Bœckia hirsuta* Brögger.
	Ceratopyge Corda, 1847	Prodr., p. 161. Type, *Olenus forficular* Sars.
Bohemillidæ ...	Bohemilla Barrande, 1872	Syst. Sil. Bohême, vol. 1, Suppl., p. 137. Type, *Bohemilla stupenda* Barr.
Conocoryphidæ	Atops Emmons, 1844	Taconic System, p. 20. Type, *Atops trilineatus* Emmons.
	Conocoryphe Corda, 1847	Prodr., p. 23. Type, *Trilobite sulzeri* Schlott.
	Ptychoparia Corda, 1847	Prodr., p. 26. Type, *Conocephalus striatus*.
	Ctenocephalus Corda, 1847	Prodr., p. 26. Type, *Ctenocephalus barrandi* Corda.
	Solenopleura Angelin, 1854	Palæont. Scand., p. 26. Type, *Solenopleura holometopa* Ang.
	Liostracus Angelin, 1854	Palæont. Scand., p. 27. Type, *Liostracus aculeatus* Angelin.
	Aneuacanthus Angelin, 1854	Palæont. Scand., p. 5. Type, *Aneuacanthus acutangulus* Ang.
	Anomocare Angelin, 1854	Palæont. Scand., p. 24. Type, *Anomocare aculeatus* Angelin.
	Angelina Salter, 1847	Mem. Geol. Survey United Kingdom, decade xi. Type *Angelina sedgwicki* Salter.
	Agraulos Corda, 1847	Prodr., p. 26. *Agraulus certicephalus* Barr.
	Dorypyge Dames, 1884	China (Richthofen), vol. 4, p. 23.
	Bathyurus Billings, 1859	Canadian Naturalist, vol. 4, p. 364. Type, *Asaphus extans* Hall.
	Bathyurella Billings, 1865	Pal. Foss., vol. 1, p. 262. *B. marginatus*, *B. nitidus*, *B. expansus* Billings.
	Chariocephalus Hall, 1863	Sixteenth Rept. New York State Cab. Nat. Hist., p. 175. Type, *Chariocephalus whitfieldi* Hall.
	Corynexochus Angelin, 1854	Palæont. Scand., p. 59. Type, *Corynexochus spinulosa* Ang.
	Ellipsocephalus Zenker, 1833	Beitfäge Nat. Urwelt, p. 31. Type, *Ellipsocephalus ambiguus* Zenker=*Ellipsocephalus hoffi* Schlott.
	Ptychaspis Hall, 1863	Sixteenth Rept. New York State Cab. Nat. Hist., p. 170. Type, *Dikelocephalus miniscænsis* Owen.
	Sao Barrande, 1846	Notice Prélim. Syst. Sil. Bohême, p. 13. Type *Sao hirsuta* Barr.

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First series, with grooved pleuræ—Continued.

Family.	Genera.	Reference.
Proetidæ	Proetus Steininger, 1831	Mém. Soc. Géol. France, vol. 1, p. 355. Type, *Proetus cuvieri* Steininger.
	Dechenella Kayser, 1880	Zeitschr. Deutsch. geol. Gesell., Berlin, vol. 32, p. 703. Type, *Dechenella verneuili* Barr.
	Prionopeltis Corda, 1847 (*Phæton* Barr., *Phæthonides* Angelin).	Prodr., p. 121. Type, *Prionopeltes polydorus* Corda.
	Brachymetopus McCoy, 1847	Annals Mag. Nat. Hist., 1st series, London, vol. 20, p. 229. Type, *Phillipsia maccoyi* Portlock.
	Cyphaspis Burmeister, 1843.....	Org. Trilobiten (Ray Soc. Ed., p. 98). *Phacops certophthalma* Gold.
	Arethusina Barrande, 1852.....	Syst. Sil. Bohême, vol. 1, p. 494. *Arethusina konincki* Barr.
	Harpides Beyrich, 1846	Untersuch. Trilobiten, p. 34. Type, *Harpides hospes* Beyrich.
	Carmon Barrande, 1872	Syst. Sil. Bohême, vol. 1, suppl., p. 19. Type, *Carmon multilus* Barr.
	Cyphoniscus Salter, 1852.....	Rept. 22d Meeting Brit. Assoc. Adv. Sci., Trans. Sec., p. 95. Type, *Cyphoniscus socialis* Salter.
Phillipsidæ	Phillipsinella Novák, 1885	Sitzungsbe. rböhm. Gesell. Wiss., 1885. Author's edition, p. 4. Type, *Phillipsinella parabola* Barr.
	Phillipsia Portlock, 1843.....	Geol. Rept. Londonderry, etc., p. 305. Type, *Phillipsia kelli* Portlock=*Asaphus gemmulifera* Phillips.
	Griffithides Portlock, 1843.....	Geol. Rept. Londonderry, etc., p. 310. Type, *Griffithides longiceps* Portlock.
Dalmanitidæ ..	Phacops Emmrich, 1839.....	De Trilob., etc., p. 18. Type, *Phacops latifrons* Bronn.
	Dalmanites Emmrich, 1844.....	Zur Nat. Trilobiten, etc., p. 15. Barrande's Syst. Sil. Bohême, vol. suppl., p. 27. Type, *Dalmanites caudata* Brünnich.
	Coronura Hall & Clarke, 1888.....	Pal. New York, vol. 7, p. xxxii. Type, *Coronura aspectens* Conrad.
	Cryphæus Green, 1837	Am. Jour. Sci., 1st series, vol. 32, p. 343. Type, *Cryphæus boothi* Green.
	Chasmops McCoy, 1849	Annals Nat. Hist., 2d series, vol. 4; also Contrib. to Palæont., p. 143. Type, *Calymene odini* Eichwald.
Calymenidæ ...	Calymene Brongniart, 1822.....	Crust. Foss., p. 11. Type, *Calymene tuberculata* Brünnich.
	Homalonotus Koenig, 1825.....	Icones Foss. Sectiles, p. 7. Type, *Homalonotus knighti* Koenig.
	Bavarilla Barrande, 1868.....	Faune Sil. des environs de Hof en Bavière, p. 75. Type, *Bavarilla hofensis* Barr.
Lichasidæ	Lichas Dalman, 1826.....	Paläad., p. 53. Type, *Lichas laciniatus* Wahl.

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First series, with grooved pleuræ—Continued.

Family.	Genera.	Reference.
Trinucleidæ ...	Trinucleus Lhlwyd, 1698 (Cryptolithus Green, 1832).	Murchison's Silurian Syst., 1839, p. 659. Type, *Trinucleus fimbriatus*.
	Ampyx Dalman, 1826.	Palæad., p. 53. Type, *Ampyx nasuta* Dalman.
	Dionidæ Barrande, 1847.....	Neues Jahrb. für Mineral., 1847, pt. 4, p. 391; Syst. Sil. Bohême, vol. 1, p. 540. Type, *Dionidæ formosa* Barr.
	Subgenera:	
	1. *Salteria* Thomson, 1864.....	Mem. Geol. Survey United Kingdom, decade xi, pl. 7, p. 1. Type, *Salteria primæva* Thomson.
	2. *Endyminia* Billings, 1862...	Pal. Foss., vol. 1, p. 93. Type, *Endyminia meeki* Billings.
Æglinidæ.....	Æglina Barrande, 1852.....	Syst. Sil. Bohême, vol. 1, p. 663. Type, *Æglina rediviva* Barr.
Illænuridæ	Illænurus Hall, 1863	Sixteenth Rept. New York State Cab. Nat. Hist., p. 176. Type, *Illænurus quadratus* Hall.
Asaphidæ	Asaphus Brongniart, 1822	Crust. Foss., p. 17. Type, *Asaphus expansus* Wahl.
	Ptychopyge Angelin, 1854	Palæont. Scand., p. 51. Type, *Ptychopyge appanata* Ang.
	Brachyaspis Salter, 1866.....	Mon. Brit. Trilobites, p. 167. Type, *Asaphus rectifrons* Portlock and *Asaphus lævigatus* Angelin.
	Megalaspis Angelin, 1852.....	Palæont. Scand., p. 15. Type, *Megalaspis gigas* Angelin.
	Ogygia Brongniart, 1822	Crust. Foss., p. 26. Type, *Asaphus buchi* Brong.
	Barrandia McCoy, 1849	Annals Nat. Hist., 2d series, vol. 4, p. 409. Type, *Barrandia cordai* McCoy.
	Niobe Angelin, 1852	Palæont. Scand., p. 13. Type. *Asaphus frontalis* Dalman.
	Asaphellus Callaway, 1877.....	Quart. Jour. Geol. Soc. London, vol. 33, p. 653. Type, *Asaphellus homfrayi* Salter.
	Nileus Dalman, 1826	Palæad., p. 49. Type, *Nileus armadillo* Dalman.

Second series, with plane pleuræ.

Styginidæ	Styginia Salter, 1853	Rept. 22d Meeting Brit. Assoc. Adv. Sci., p. 59. Type, *Styginia latifrons* Portlock.
Illænidæ.....	Illænus Dalman, 1826	Palæad., p. 51. Type, *Illænus crassicauda* Wahl.; Nova Acta Reg. Soc. Sci. Upsal., vol. 8, p. 27, pl. 2, figs. 3, 5, 6. (Not. pl. 7, figs. 5, 6 = *Illænus esmarki*.)
	Dysplanus Burmeister, 1843.....	Organization Trilobites, p. 105 (Ray Soc. Ed. 1846). Type, *Dysplanus centrotus* Dalm.
	Bumastus Murchison, 1839.....	Sil. Syst, p. 656. Type, *Bumastus barriensis* Murch.
	Panderia Volborth, 1863	Mém. Acad. Sci. St.-Pétersbourg, 7th series, vol. 6, No. 2, p. 31. Type, *Panderia triquetra* Volb.

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Third series, with ridged pleuræ (pleure à bourrelet, Barrande).

Family.	Genera.	Reference.
Acidaspidæ	Acidaspis Murchison, 1839 (*Odontopleura* Emmrich, 1839).	Silurian System, p. 558. Type, *Acidaspis brightii* Murch.
Ceraurides	Ceraurus Green, 1832 (*Cheirurus* Beyrich, 1845).	Mon. Trilobites N. A., p. 83. Type, *Ceraurus pleurexanthemus* Green.
	Sphærexochus Beyrich, 1845	Ueber einige böhm. Trilobiten, p. 19. Type, *Sphærexochus mirus* Beyrich.
	Areia Barrande, 1872	Syst. Sil. Bohême, vol. 1, suppl., p. 96. Type, *Areia bohemica* Barr.
	Deiphon Barrande, 1852	Syst. Sil. Bohême, vol. 1, p. 814. Type, *Deiphon forbesi* Barr.
	Placoparia Corda, 1847	Prodr., p. 128. Type, *Placoparia zippi* Boeck.
	Staurocephalus Barrande, 1852	Syst. Sil. Bohême, vol. 1, p. 810. Type, *Staurocephalus murchisoni* Barr.
	Onycopyge Woodward, 1880	Geol. Mag., decade 2, vol. 7, p. 97. Type, *Onycopyge liversidgei* Woodward.
Amphionidæ	Amphion Pander, 1850	Beiträge Geog. Russischen Reiches, p. 439. Type, *Amphion fischeri* Eichwald.
	Cromus Barrande, 1852	Syst. Sil. Bohême, vol. 1, p. 821. Type, *Cromus intercostatus* Barr.
Encrinurides	Encrinurus Emmrich, 1844 (Cryptonymus Eichwald).	Zur Nat. Trilobiten, p. 16. Type, *Trilobus punctatus* Brünnich.
	Cybele Loven, 1845	Svenska Akad. Förhandl., 1845, p. 110. Type, *Calymene bellatula* Dalman.
	Dindymene Corda, 1847	Prodr., p. 119. Type, *Dindymene frederico-augusti* Corda.
Brontides	Bronteus Goldfuss, 1843	Beiträge Petrefact., Nova Acta Physico-Med., vol. 19, p. 360. Type, *Brontes flabellifer* Gold.

Fourth series.

Agnostides	Agnostus Brongniart, 1822	Hist. Crust. Foss., p. 38. Type, *Agnostus pisiformis.*
	Shumardia Billings, 1862	Pal. Foss., vol. 1, p. 92. Type, *Shumardia granulosa* Billings.
	Microdiscus Emmons, 1856	Am. Geology, vol. 1, pt. 2, p. 116. As defined by Chas. D. Walcott, 1886. Type, *M. punctatus* and *M. speciosus.*

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A CATALOGUE OF NORTH AMERICAN SPECIES OF TRILOBITES.

[Current names are printed in bold face type; synonyms in *Italic*.]

Acantholoma Conrad, 1840; 3d Annual Rept. Pal. Dept. New York Geol. Survey, p. 205. (See **Acidaspis.**)

—— *spinosa* Conrad. (See **Acidaspis tuberculatus.**)

Acidaspis Murchison, Silurian System, 1839, p. 658.

Type, *Acidaspis brightii* Murch., Sil. Syst., p. 658, pl. 14, figs. 10, 15.

Syn., *Ceratocephala* Warder, 1838; Am. Jour. Sci., 1st series, vol. 34, p. 377.

Odontopleura Emmrich, 1839; De Tril., p. 53.

Arges Goldfuss (in part), Neues Jahrbuch für Mineral., 1843, pp. 544, 556.

Polyeris Rouault, 1846; Bull. Soc. Géol. France, vol. 4, p. 320.

Selenopeltis Corda, 1847; Prodr., p. 34.

Trapelocera Corda, 1847; Prodr., p. 158.

Discranurus Conrad, 1841; 5th Ann. Rept. Pal. Dept. New York Geol. Survey, p. 48.

—— **anchoralis** Miller, 1875; Cincinnati Quart. Jour. Sci., vol. 2, p. 349, figs. 2–4. Hudson.

—— *armatus.* (See **Acidaspis eriops.**)

—— **callicera** Hall, 1888; Pal. New York, vol. 7, pp. 69, 224, pl. 16 b, figs. 1–3. Upper Helderberg.

—— [*Ceratocephala*] **ceralepta** Anthony, 1838; Am. Jour. Sci., 1st series, vol. 34, p. 379, figs. 1, 2. Hudson.

—— **ceralepta** Meek, 1873; Pal. Ohio, vol. 1, p. 169, pl. 14, figs. 8–9.

—— **ceralepta** Miller, 1874; Cincinnati Quart. Jour. Sci., vol. 1, p. 130.

—— **cincinnatiensis** Meek, 1873; Pal. Ohio, vol. 1, p. 167, pl. 14, fig. 3. Hudson.

—— **cincinnatiensis** Miller, 1874; Cincinnati Quart. Jour. Sci., vol. 1, p. 130.

—— [*Ceraurus*] **crosotus** Locke, 1842; Am. Jour. Sci., 1st series, vol. 44, p. 347, fig. Hudson.

—— **crosotus** James, 1871; Catalogue Fossils Cincinnati Group, p. 14.

—— **crosotus** Meek, 1873; Pal. Ohio, vol. 1, p. 165, pl. 14, figs. 10 a, b.

—— **crosotus** Miller, 1874; Cincinnati Quart. Jour. Sci., vol. 1, p. 129.

—— **danai** Hall, 1862; Geol. Wisconsin, vol. 1, p. 432. Niagara.

Syn., *Acidaspis ida* (Winchell and Marcy) Hall, 20th Rept. New York State Cab. Nat. Hist., p. 389.

—— **danai** Hall, 1867; 20th Rept. New York State Cab. Nat. Hist., p. 333, pl. 21, figs. 8, 9.

—— **danai** Hall, 1870; 20th Rept. New York State Cab. Nat. Hist., p. 423, pl. 21, figs. 8, 9 (rev. ed.).

—— [*Teratasp is*] **eriops** Hall, 1876; Illus. Devonian Foss. Crust., pl. 19, figs. 4–7, 10, 11, 12. (See **Lichas** (*Conolichas*) **eriops** Hall.)

—— **fimbriata** Hall, 1879; Description of New Species from the Niagara Group, p. 20. Niagara.

—— **fimbriata** Hall, 1882; Trans. Albany Inst., vol. 10, p. 76.

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Acidaspis fimbriata Hall, 1883; 11th Rept. Geol. Nat. Hist. Indiana, p. 334, pl. 33, fig. 11.

—— [*Teratasp*is] **grandis** Hall, 1876; Illus. Devonian Foss. Crust., pl. 17, figs. 1–8; pl. 18, figs. 1–4. (See **Lichas** (*Teratasp*is) **grandis** Hall.)

—— **halli** Shumard, 1855; 1st and 2d Rept. Geol. Survey Missouri, pt. 2, p. 200, pl. B, figs. 7 a, b, c. **Trenton.**

—— [*Discranurus*] **hamata** Conrad, 1841; 5th Ann. Rept. Pal. Dept. New York Geol. Survey, p. 48, pl. 1, fig. 1. **Lower Helderberg.**

—— [*Discranurus*] **hamata** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., pl. 2, fig. 1. Republication of pl. 2, 5th Ann. Rept. Pal. Dept. New York Geol. Survey.

—— **hamata** Hall, 1859; Pal. New York, vol. 3, p. 371, pl. 79, figs. 15–19.

—— **hamata** Meek and Worthen, 1868; Geol. Survey Illinois, vol. 3, p. 390, pl. 7, fig. 17.

—— **horani** Billings, 1857; Geol. Survey Canada, p. 341. **Trenton.**

—— **horani** Billings, 1863; Geol. Survey Canada, p. 190, fig. 190.

—— *ida* Winchell and Marcy, 1865; Mem. Boston Soc. Nat. Hist., vol. 1, p. 106, pl. 3, fig. 13.

—— **o'nealli** Miller, 1875; Cincinnati Quart. Jour., vol. 2, p. 86, fig. 9. **Hudson.**

—— **ortoni** Foerste, 1887; Bull. Denison Univ., vol. 2, p. 90, pl. 8, fig. 1.

—— **parvula** Walcott, 1877; Advanced sheets 31st Rept. New York State Mus., p. 16. **Trenton.**

—— **parvula** Walcott, 1879; 31st Rept. New York State Mus., p. 69.

—— **romingeri** Hall, 1888; Pal. New York, vol. 7, pp. 71, 224, pl. 16 b, figs. 15–18. **Hamilton.**

—— *spiniger*. (See **Bathyurus spiniger.**)

—— **trentonensis** Hall, 1847; Pal. New York, vol. 1, p. 240, pl. 64, figs. 4 af. **Trenton.**

—— **trentonensis** Emmons, 1855; American Geology, vol. 1, pt. 2, p. 216, fig. 73.

—— **tuberculatus** Conrad, 1840; 3d Ann. Rept. Pal. Dept. New York Geol. Survey, p. 205. **Lower Helderberg.**

Syn., *Acantholoma* Conrad, 1840; 3d Ann. Rept. Pal. Dept. New York Geol. Survey, p. 205, fig. 3.

Acantholoma spinosa Conrad, 4th Ann. Rept. Pal. Dept. New York Geol. Survey, p. 39, pl. 1, fig 3.

—— **tuberculatus** Hall, 1859; Pal. New York, vol. 3, p. 368, pl. 79, figs. 1–14.

—— **tuberculatus** Hall, 1861; 15th Rept. New York State Cab. Nat. Hist., pl. 2, fig. 3.

Actinurus De Castelnau, 1843; Sil. Syst. de l'Amér., p. 21. (See **Lichas boltoni.**)

Aglaspis Hall, 1862; Canadian Naturalist, vol. 7, p. 445, figure. Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 181.

Type, *Aglaspis barrandi* Hall.

—— **barrandi** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 181, pl. 11, figs. 7–16. **Potsdam.**

—— **eatoni** Whitfield, 1880; Ann. Rept. Geol. Survey Wisconsin, p. 52. **Potsdam.**

—— **eatoni** Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 192, pl. 10, fig. 11.

Agnostus Brongniart, 1822; Hist. Nat. Crust. Foss., p. 38.

Type, *Agnostus pisiformis*, idem., p. 38, pl. 4, figs. 4 a, 4 b.

Syn., *Battus* Dalman, 1826; Palæad., p. 33.

Trinodus McCoy, 1846; Sil. Foss. Ireland, p. 56.

Phalacroma Corda (in part), 1847; Prodr., p. 158.

Mesospheniscus Corda, 1847; Prodr., p. 46 (*Agnostus integer*).

Diplorrhina Corda, 1847; Prodr., p. 46.

Condylopyge Corda, 1847; Prodr., p. 50 (*Agnostus rex*).

Lejopyge Corda, 1847; Prodr., p. 51 (*Agnostus lævigatus*).

Arthrorhachis Corda, 1847; Prodr., p. 114 (*Agnostus tardus*).

Peronopsis Corda, 1847; Prodr., p. 115 (*Agnostus interger*).

Pleuroctenium Corda, 1847; Prodr., p. 116 (*Agnostus granulatus*).

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Agnostus acadicus Hartt, 1868; Acadian Geology, p. 655, fig. 229 (3d ed.). St. John.
Syn., *Similis* Hartt, 1868; Acadian Geology, p. 656 (3d ed.).
Similis Hartt (Walcott), 1884; Bull. U. S. Geol. Survey, No. 10, p. 22.
—— **acadicus** Walcott, 1884; Bull. U. S. Geol. Survey, No. 10, p. 22, pl. 2, figs. 2, 2 a, c.
—— **americanus** Billings, 1860; Canadian Naturalist, vol. 5, p. 302, fig. 1. Quebec.
—— **americanus** Billings, 1865; Pal. Foss., vol. 1, p. 395, fig. 372.
—— **bidens** Meek, 1873; 6th Ann. Rept. U. S. Geol. Survey Territories, p. 463. Potsdam.
—— **bidens** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 26, pl. 9, figs. 13, 13 a.
—— **canadensis** Billings, 1860; Canadian Naturalist, vol. 5, p. 304, fig. 3. Quebec.
—— **canadensis** Billings, 1865; Pal. Foss., vol. 1, p. 397, fig. 374.
—— **coloradoensis** Shumard, 1861; Am. Jour. Sci., 2d series, vol. 32, p. 218. Potsdam.
—— **communis** Hall and Whitfield, 1877; U. S. Geol. Expl. 40th Par., vol. 4, p. 228, pl. 1, figs. 28, 29. Potsdam.
—— **communis** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 27.
—— **disparlis** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 179, pl. 10, figs. 25–27. Potsdam.
—— **fabius** Billings, 1865; Pal. Foss., vol. 1, p. 298, fig. 289. Quebec.
—— **glabba** Billings, 1865; Pal. Foss., vol. 1, p. 297, fig. 288. Quebec.
—— **interstrictus** White, 1874; Prelim. Rept. Invert. Foss., p. 7. Potsdam.
—— **interstrictus** White, 1877; U. S. Geog. and Geol. Survey W. 100th Meridian, p. 38, pl. 2, figs. 5 a, 5 b.
—— **interstrictus** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 149, pl. 16, figs. 6, 6 a.
—— **interstrictus** Walcott, 1888; Am. Jour. Sci., 3d series, vol. 36, p. 166.
—— sp.? Rominger, 1887; Proc. Acad. Nat. Sci. Phila., p. 18.
—— **josepha** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 178, pl. 6, figs. 54, 55. Potsdam.
—— *lobatus* Hall. (See **Microdiscus lobatus**.)
—— **maladensis** Meek, 1873; 6th Annual Rept. U. S. Geol. Survey Territories, p. 464. Calciferous.
—— **neon** Hall and Whitfield, 1877; U. S. Geol. Expl. 40th Par., vol. 4, p. 229, pl. 1, figs. 26, 27. Potsdam.
—— **neon** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 27.
—— **nobilis** Ford, 1872; Am. Jour. Sci., 3d series, vol. 3, p. 421, figs. 1, 2. Postdam.
—— **nobilis** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 150, pl. 16, fig. 7.
—— **orion** Billings, 1860; Canadian Naturalist, vol. 5, p. 304, fig. 2. Quebec.
—— **orion** Billings, 1865; Pal. Foss., vol. 1, p. 397, fig. 393.
—— **orion** Shumard, 1863; Trans. Acad. Sci. St. Louis, vol. 2, p. 105.
—— **parilis** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 179, pl. 11, figs. 23, 24. Potsdam.
—— **prolongus** Hall and Whitfield, 1877; U. S. Geol. Expl. 40th Par., vol. 4, p. 230, pl. 1, figs. 30, 31. Potsdam.
—— **prolongus** Walcott, 1884; Pal. Eureka Dist., Mon. U. S Geol. Survey, vol. 8, p. 28.
—— **richmondensis** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 24, pl. 9, fig. 10. Cambrian.
—— **seclurus** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 25, pl. 9, fig. 14. Cambrian.
—— *similis* Hartt. (See **Agnostus acadicus**.)
—— **tumidosus** Hall and Whitfield, 1877; U. S. Geol. Expl. 40th Par., vol. 4, p. 231, pl. 1, fig. 32. Potsdam.

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Agraulos Corda, 1847; Prodr., p. 23.
Type, *Arionellus certicephalus* Barrande.
Syn., *Arion* Barrande, 1846; Notice Prélim., p. 13.
Ellipsocephalus Barrande, 1846; Notice Prélim., p. 12 (not *Ellipsocephalus* Zenker) or (*Elliptocephalus* Emmons).
Arionellus Barrande, 1852; Syst. Sci. Bohême, p. 404.

—— **affinis** Billings, 1874; Pal. Foss., vol. 2, p. 72. Potsdam.

—— **affinis** Matthew, 1886; Trans. Royal Soc. Canada, vol. 2, p. 153, figs. 2, 2 a, b.

—— [*Arionellus*] **bipunctatus** Shumard, 1863; Trans. Acad. Sci. St. Louis, vol. 2, p. 101. Potsdam.

—— [*Arionellus*] **bipunctatus** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 169, pl. 7, figs. 50–57.

—— [*Arionellus* (*Agraulos*)] **convexus** Whitfield, 1878; Ann. Rept. Geol. Survey Wisconsin, 1877, p. 57. Potsdam.

—— [*Arionellus*] **convexus** Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 190, pl. 1, fig. 17.

—— [*Arionellus*] **cylindricus** Billings, 1860; Canadian Naturalist, vol. 5, p. 314, fig. 14. Quebec.

—— [*Arionellus*] **cylindricus** Billings, 1865; Pal. Foss., vol. 1, p. 406, fig. 385. (See **Ptychaspis cylindricus**.)

—— ? **globosus** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 61, pl. 9, fig. 23. Cambrian.

—— **oweni** Meek and Hayden, 1861; Proc. Acad. Nat. Sci. Phila., 1861, p. 436. Potsdam.
The species was also referred to the genera *Arionellus* and *Crepicephalus*.

—— [*Arionellus*] **oweni** Meek and Hayden, 1862; Am. Jour. Sci., 2d series, vol. 33, p. 74.

—— [*Arionellus*] **oweni** Meek and Hayden; Pal. Upper Missouri, p. 9, figs. a, b, c, pl. 1, fig. 4.
Referred by Walcott, 1884, Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 55, pl. 10, to *Ptychoparia oweni*.

—— [*Arionellus* (*Bathyurus*)] **planus** Shumard, 1861; Am. Jour. Sci., 2d series, vol. 32, p. 219. Potsdam.

—— [*Arionellus*] **pustulatus** Walcott, 1877; Advanced sheets 31st Rept. New York State Mus. Nat. Hist., p. 15. Chazy.

—— [*Arionellus*] **pustulatus** Walcott, 1877; 31st Rept. New York State Mus. Nat. Hist., p. 68.

—— [*Arionellus*] **quadrangularis** Whitfield, 1884; Bull. Mus. Nat. Hist. New York, vol. 1, p. 147, pl. 14, fig. 8. Potsdam.

—— **quadrangularis** Walcott, 1884; Bull. U. S. Geol. Survey, No. 10, p. 48, pl. 7, fig. 1.

—— **socialis** Billings, 1874; Pal. Foss., vol. 2, p. 71, fig. 40. Potsdam.

—— **socialis** Matthew, 1886; Trans. Royal Soc. Canada, vol. 2, p. 151, fig. 1, 1 a, b.

—— **strenuus** Billings, 1874; Pal. Foss., vol. 2, p. 71, fig. 41. Potsdam.

—— **strenuus** Matthew, 1886; Trans. Royal Soc. Canada, vol. 2, p. 153, figs. 3, 3 a, b.

—— *subclavatus* Billings. (See **Ptychaspis subclavatus**.)

—— [*Arionellus* (*Bathyurus*)] **texanus** Shumard, 1861; Am. Jour. Sci., 2d series, vol. 32, p. 218. Potsdam.

—— [*Arionellus*] **tripunctatus** Whitfield, 1876; Rept. Recon. Upper Missouri, p. 141, pl. 1, figs. 3–5. Potsdam.

—— [*Bathyurus?*] **woosteri** Whitfield, 1878; Ann. Rept. Geol. Survey Wisconsin, 1877, p. 56. Potsdam.

—— [*Bathyurus?*] **woosteri** Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 189, pl. 1, figs. 19–21.

Amphion Pander, 1830; Beiträge zur Geol. russischen Reiches, p. 139.
Type, *Amphion fischeri* Eichwald.

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Amphion barrandi Billings, 1865; Pal. Foss., vol. 1, p. 288, fig. 277. Quebec.
—— **canadensis** Billings, 1859; Can. Nat., vol. 4, p. 381, fig. 12, a, b. Chazy.
—— **canadensis** Billings, 1863; Geol. Survey Canada, p. 133, fig. 69.
—— **canadensis** Billings, 1865; Pal. Foss., vol. 1, p. 288, fig. 278.
—— **convexus** Billings, 1865; Pal. Foss., vol. 1, p. 322. Quebec.
—— **insularis** Billings, 1865; Pal. Foss., vol. 1, p. 290. Quebec.
—— **julius** Billings, 1865; Pal. Foss., vol. 1, p. 290, fig. 279. Quebec.
—— **matutina** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 222, pl. 5 a, fig. 6. Potsdam.
—— *multisegmentatus.* (See **Encrinurus multisegmentatus.**)
—— **nevadensis** Walcott, 1884; Pal. Eureka Dist. Mon. U. S. Geol. Survey, vol. 8, p. 94, pl. 12, fig. 13. Pogonip.
—— **salteri** Billings, 1861; Canadian Naturalist, vol. 6, p. 322, fig. 6. Calciferous.
—— **salteri** Billings, 1865; Pal. Foss., vol. 1, p. 352, fig. 399.
—— **westoni** Billings, 1865; Pal. Foss., vol. 1, p. 321, fig. 307. Quebec.
Ampyx Dalman, 1826; Palæad., p. 53 (German edition).
Type, *Ampyx nasuta* Dalman.
—— **americanus** Safford and Vodges, 1889; Proc. Phila. Acad. Nat. Sci., p. 166, figure. Trenton.
—— **halli** Billings, 1861; Pal. Foss., vol. 1, p. 24, figs. 25, a, b, c. Chazy.
—— **halli** Billings, 1862; Geol. Survey Vermont, vol. 2, p. 959, fig. 365.
—— **læviusculus** Billings, 1865; Pal. Foss., vol. 1, p. 295, fig. 285. Quebec.
—— **normalis** Billings, 1865; Pal. Foss., vol. 1, p. 295, fig. 286. Quebec.
—— **rustilius** Billings, 1865; Pal. Foss., vol. 1, p. 296. Quebec.
—— **semicostatus** Billings, 1865; Pal. Foss., vol. 1, p. 297, fig. 287. Quebec.
Angelina Salter, 1864; Mem. Geol. Survey United Kingdom, decade xi, pl. 7.
Type, *Angelina sedgwicki* Salter.
—— **hitchcocki** Whitfield, 1884; Bull. Am. Mus. Nat. Hist., New York, vol. 1, p. 148, pl. 14, fig. 13. (See **Protypus hitchcocki.**) Potsdam.
Anomocare Angelin, 1852; Palæont. Scand., p. 24.
Type, *Anomocare aculeatus* Ang., pl. 18, fig. 6.
—— [*? Conoceph.*] **depressus** Shumard, 1861; Am. Jour. Sci., 2d series, vol. 32, p. 219. Potsdam.
—— [*Lonchocephus*] **hamulus** Owen, 1852; Geol. Survey Wisconsin, Iowa, and Minnesota, p. 576, pl. 1 a, figs. 8–12. Potsdam.
—— undet. Trilobite, Owen, 1848; Geol. Reconnoissance Chippewa Land Dist., p. 15, pl. 7, fig. 5.
—— [*Conocephalites*] **hamulus** Shumard, 1863; Acad. Sci. St. Louis, vol. 2, p. 104.
—— [*Conocephalites*] **hamulus** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 166, pl. 7, figs. 43, 44; pl. 8, figs. 25, 26.
—— **hamulus** Dames, 1884; China (Richthofen), vol. 4, p. 24.
—— [*Conocephalites*] **patersoni** Hall, 1863; Rept. New York State Cab. Nat. Hist., p. 159, pl. 7, figs. 45, 46. Potsdam.
—— **patersoni** Dames, 1884; China (Richthofen), vol. 4, p. 24.
—— ? **parvum** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 59, pl. 9, fig. 17. Cambrian.
—— ? **parvum** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 209, pl. 25, fig. 1.
—— [*Crepicephalus ?*] **wisconsensis** Owen, 1852; Rept. Geol. Survey Wisconsin, Iowa, and Minnesota, pl. 1, fig. 13. (The upper figure only; the other figured specimen belongs to *Dikelocephalus granulosus.*)
—— [*Crepicephalus*] **wisconsensis** Shumard, 1863; Trans. Acad. Sci. St. Louis, vol. 2, p. 103.

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Anomocare [*Crepicephalus*] **wisconsensis** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 164, pl. 7, figs. 39–41; pl. 8, figs. 22, 23, 24, 27, 28.
Syn., *Dikelocephalus latifrons* (Shumard) Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 165, pl. 7, fig. 40.
—— **wisconsensis** Dames, 1884; China (Richthofen), vol. 4, p. 24. Potsdam.
Anopolenus Salter, 1864; Geol. Mag., vol. 1, p. 236.
Type, *Anopolenus henrici* Salter; Quar. Jour. Geol. Soc. London, vol. 20, p. 236, pl. 13, figs. 4, 5. (See, also, **Anopolenus salteri** Hicks; same journal, vol. 21, p. 478, pl. , fig. 1.
—— **venustus** Billings, 1874; Pal. Foss., vol. 2, p. 73, fig. 42. Potsdam.
Arethusina Barrande, 1852; Syst. Sil. Bohême, vol. 1, p. 493.
Type, *Arethusina konincki* Barrande.
—— **americana** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 62, pl. 9, fig. 27. Cambrian.
Arges. (See **Lichas**.)
Arges, subgenus *Lichas*, Hall and Clarke, 1888; Pal. New York, vol. 7, p. lx.
—— *phlyctanodes* Green. (See **Lichas phlyctanodes**.)
—— *arionellus*. (See **Agraulos**.)
Asaphiscus Meek, 1873; 6th Ann. Rept. U. S. Geol. Survey Territories, p. 485 (footnote).
—— [*Bathyurellus* (*Asaphiscus*)] **bradleyi** Meek, 1873; 6th Ann. Rept. U. S. Geol. Survey Territories, p. 484. Cambrian.
—— **bradleyi** Meek, 1873; 6th Ann. Rept. U. S. Geol. Survey Territories, p. 485.
—— **wheeleri** Meek, 1873; 6th Rept. U. S. Geol. Survey Territories, p. 485 (footnote). Cambrian.
—— **wheeleri** White, 1875; Geog. and Geol. Survey West 100th Meridian, vol. 4, p. 43, pl. 2, figs. 1 a–f.
—— **wheeleri** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 220, pl. 31, figs. 3, 3 a.
Asaphus Brongniart, 1822; Hist. Nat. Crust. Foss., p. 18, pl. 2, fig. 1 a, b.
Type, *Asaphus expansus* Linné.
Syn., *Cryptonymus*, Eichwald, 1825; (in part) not *Cryptonymus* Eichwald, 1840.
Isotelus De Kay, 1822; Annals Lyceum Nat. Hist. New York, vol. 1, p. 174.
Hemicrupturus Green, 1832; Mon. Tril. North America, p. 20.
—— *acantholeurus*. (See **Dalmanites acantholeurus**.)
—— **alacer** Billings, 1866; Catalogue Sil. Foss. Anticosti, p. 26, fig. 9.
—— *aspectans*. (See **Dalmanites aspectans**.)
—— **astragalotes** Green, 1834; Am. Jour. Sci., 1st series, vol. 25, p. 335.
—— **astragalotes** Green, 1835; Suppl. Mon. Tril. N. A., p. 11, cast 37.
Probably *Phacops rana* Green.
—— *barrandi*. (See **Ogygia barrandi**.)
—— **canadensis** Chapman, 1856; Canadian Jour., vol. 1, p. 482. Utica Slate.
—— **canadensis** Chapman, 1858; Canadian Jour., vol. 2, p. 47.
—— **canadensis** Chapman, 1858; Canadian Jour., vol. 3, p. 230, figure.
—— **canadensis** Chapman, 1859; Canadian Jour., vol. 4, p. 1, figure.
—— **canadensis** Chapman, 1859; Annals Nat. Hist., 3d series, vol. 2, p. 9, fig. 1.
—— **canadensis** Billings, 1863; Geol. Survey Canada, p. 204, fig. 201.
From a personal study of the species collected on the Georgian Bay, Canada, I am inclined to refer *Asaphus halli* and *A. hincksii* to *Asaphus canadensis* Chapman.
—— [*Isotelus*] **canalis** Conrad MSS. Chazy.
—— [*Isotelus*] **canalis** Hall, 1847; Pal. New York, vol. 1, p. 25, pl. 4 *bis*, figs. 17–19.
—— **canalis** Billings, 1865; Pal. Foss., vol. 1, p. 255; also p. 352, fig. 340 (not Conrad sp.).
—— **canalis** Billings, 1862; Geol. Vermont, vol. 1, p. 299, pl. 12, fig. 5.
This species is probably *Asaphus platycephalus*.

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Asaphus canalis Whitfield, 1886; Bull. Am. Mus. Nat. Hist., New York, vol. 1, p. 336, pl. 34, figs. 1–8.
—— **canalis** Whitfield, 1889; Bull. Am. Mus. Nat. Hist., New York, vol. 2, p. 64, pls. 11, 12.
—— **caribouensis** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 98, pl. 12, figs. 7–7 a, b. Pogonip.
—— *caudatus*. (See **Dalmanites limulurus.**)
—— *cordieri*. (See **Dalmanites limulurus.**)
—— *corycæus*. (See **Proetus coryocæus.**)
—— *crypturus*. (See **Homalonotus crypturus.**)
—— **curiosus** Billings, 1865; Pal. Foss., vol. 1, p. 318, fig. 305. Quebec.
—— ? **curiosus** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 98, pl. 12, fig. 15.
—— *denticulatus*. (See **Dalmanites denticulatus.**)
—— *ditmarsiæ* Honeyman, 1879; Proc. Nova Scotia Inst. Nat. Sci., vol. 5, p. 18. (See **Homalonotus crypturus** Green.) Clinton?
—— **duirus** Green, 1839; Am. Jour. Sci., 1st series, vol. 37, p. 40. Hudson.
—— *edwardi*. (See **Dalmanites limulurus.**)
—— **emoryi** Hall, 1857; Rept. U. S. Mexican Boundary Survey, vol. 1, pl. 20, fig. 5. Not defined.
—— *extans*. (See **Bathyurus extans.**)
—— *gigas*. (See **Asaphus platycephalus.**)
—— [*Megalaspis?*] **goniocerous** Meek, 1873; 6th Ann. Rept. U. S. Geol. Survey Territories, p. 480. Quebec.
—— **goniurus** Billings, 1860; Canadian Naturalist, vol. 5, p. 324. Quebec.
—— **goniurus** Billings, 1865; Pal. Foss., vol. 1, p. 415.
—— *halli*. (See **Cryphæus boothi.**)
—— **halli** Chapman, 1858; Annals Nat. Hist., 3d series, vol. 2, p. 14, fig. 2. Trenton and Utica.
—— **halli** Chapman, 1858; Canadian Jour., 2d series, vol. 3, p. 236, figure. This species is the same as *Asaphus canadensis* Chapman.
—— *hincksii* Chapman, 1859; Canadian Jour. Industry, Sci. and Arts, vol. 4, p. 2, figure. (See **Asaphus canadensis** Chapman.) Utica.
—— **homalononotoides** Walcott, 1877; Advanced sheets 31st Rept. New York State Mus. Nat. Hist., p. 20. Trenton.
—— **homalononotoides** Walcott, 1879; 31st Rept. New York State Mus. Nat. Hist., p. 71.
—— *homalononotoides* Whitfield (not Walcott), 1882; Geol. Wisconsin, vol. 4, p. 237. (See **Asaphus triangulatus.**)
—— **huttoni** Billings, 1865; Pal. Foss., vol. 1, p. 271, fig. 256. Quebec.
—— **illænoides** Billings, 1860; Canadian Naturalist, vol. 5, p. 323.
—— **illænoides** Billings, 1865; Pal. Foss., vol. 1, p. 414.
—— [*Isotelus*] **iowensis** Owen, 1852; Rept. Geol. Survey Wisconsin, Iowa, and Minnesota, p. 577, pl. 2 a, figs. 1–7. Trenton.
—— *laticostatus*. (See **Dalmanites anchiops.**)
—— ? **latimarginata** Hall, 1847; Pal. New York, vol. 1, p. 253, pl. 66, figs. 4 a, b. Utica.
—— *limulurus*. (See **Dalmanites limulurus.**)
—— **marginalis** Hall, 1847; Pal. New York, vol. 1, p. 24, pl. 4 *bis*, fig. 15. Chazy.
—— **marginalis** Emmons, 1855; Am. Geology, vol. 1, pt. 2, p. 235, pl. 3, fig. 16.
—— [*Isotelus*] **maximus** Locke, 1838; 2d Ann. Rept. Geol. Survey Ohio, p. 246, figs. 8, 9. Trenton and Hudson.
Syn., *Isotelus megistos* Locke, 1841; Trans. Am. Assoc. Geol. Nat., p. 221, pl. 6.
Isotelus megistos Locke, 1842; Am. Jour. Sci., 1st series, vol. 42, p. 366, pl. 3.

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Syn., *Isotelus megistos* Meek, 1873; Pal. Ohio, vol. 1, p. 157, pl. 14, fig. 13.
Isotelus megistos Miller, 1874, Cincinnati Quart. Jour. Sci., vol. 1, p. 137.
Asaphus megistos Walcott, 1884; Science, March 7, fig. 1, vol. 3, p. 200.

Asaphus megalopthalmus Troost, 1840; 5th Geol. Rept. Tennessee, p. 57. Trenton?

—— **micropleurus** Green, 1835; Suppl. Mon. Tril. North America, p. 21, cast No. 41.

—— *micrurus*. (See **Dalmanites micrurus.**)

—— *morrisi* Billings, 1865; Pal. Foss., vol. 1, p. 272, fig. 257, Syn. to **Asaphus huttoni** Billings.

—— *murchisoni* Castelnau, Syn. to **Asaphus platycephalus** Stokes.

—— *myrmecophorus*. (See **Dalmanites myrmecophorus.**)

—— *nasutus*. (See **Dalmanites nasutus.**)

——? *nodostriatus* Hall, 1847; Pal. New York, vol. 1, p. 248, pl. 61, figs. 1 a, b. (See **Bathyurus extans** Hall.)

—— **notans** Billings, 1866; Catalogue Silurian Foss. Anticosti, p. 25, fig. 8.
Compare *Asaphus maximus* Locke.

——? **obtusus** Hall, 1847; Pal. New York, vol. 1, p. 24, pl. 4 *bis*, fig. 14. Chazy.

—— **obtusus** Emmons, 1855; American Geology, vol. 2, pt. 2, p. 236, pl. 3, fig. 14.

—— **pelops** Billings, 1865; Pal. Foss., vol. 1, p. 317, fig. 304. Quebec

—— **platycephalus** Stokes, 1823; Trans. Geol. Soc. London, 2d series, vol. 1, p. 208, pl. 27. Trenton.

Syn., *Isotelus gigas* De Kay, 1824; Annals Lyceum Nat. Hist. New York, vol. 1, p. 176, pl. 12, fig. 1.
Isotelus planus De Kay, 1824; Annals Lyceum Nat. Hist. New York, vol. 1, p. 178, pl. 13, fig. 7.
Asaphus gigas Dalman, 1826; Palæad., p. 70.
Asaphus gigas and *planus* Dalman, 1826; Palæad., p. 70.
Isotelus gigas Green, 1832; Monthly Am. Jour. Geol., p. 560.
Isotelus gigas Green, 1832; Mon. Tril. N. A., p. 71, cast 21, 22.
Isotelus planus Green, 1832; Monthly Am. Jour. Geol., p. 560; Mon. Tril. N. A., p. 68, cast 23.
Isotelus stegops Green, 1832; Mon. Tril. N. A., p. 71, cast 26, 27.
Brongniartia isotelea Eaton, 1832; Geological Text Book, p. 33, pl. 2, fig. 22.

—— **platycephalus** Bronn, 1835; Lethæa Geogn., vol. 1, p. 115, pl. 9, fig. 8.

Syn., *Isotelus gigas* Milne-Edwards, 1840; Crust., vol. 3, p. 298.

—— **platycephalus** Buckland, 1840; Bridgw. Treatise, vol. 2, p. 76, pl. 63, fig. 12.

—— **platycephalus** Burmeister, 1843; Org. Trilobites, p. 110, pl. 2, fig. 12 (Ray Soc. ed., 1846).

Syn., *Isotelus gigas* Portlock, 1843; Geol. Rept. Londonderry, p. 295, pl. 7, fig. 1; pl. 8, fig. 1.
Isotelus planus Portlock, 1843; Geol. Rept. Londonderry, p. 295, pl. 7, figs. 2, 3.
Isotelus gigas Hall, 1847; Pal. New York, vol. 1, p. 231, pls. 60-63.
Isotelus gigas Emmons, 1855; Am. Geology, vol. 1, pt. 2, p. 215, pl. 16, fig. 12.

—— [*Isotelus*] **platycephalus** Bronn and Roemer, 1851-'56; Lethæa Geogn., vol. 1, p. 632, pl. 9, fig. 8; pl. 9[1], fig. 5.

—— **platycephalus** Nieszkowski, 1857; Mon. Sil. Ostseeprovinz, Tril., p. 37.

Syn., *Isotelus gigas* Rogers, 1858; Geol. Survey Pennsylvania, vol. 2, p. 819, fig. 610.

—— **platycephalus** Billings, 1863; Geol. Survey Canada, p. 184, fig. 183.

Syn., *Asaphus* (*Isotelus*) *gigas* Salter, 1864; Mon. Brit. Tril., p. 161, pl. 24, figs. 1-5; pl. 25, fig. 1 (var.).
Asaphus (*Isotelus*) *gigas* Salter, 1864; Mem. Geol. Survey United Kingdom, decade xi, pl. 3.

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Asaphus platycephalus Billings, 1870; Quart. Jour. Geol. Soc. London, vol. 26, p. 486, pls. 31, 32.

Syn., *Isotelus gigas* Miller, 1874; Cincinnati Quart. Jour. Sci., vol. 1, p. 138.

—— **platyleurus** Green, 1837; Am. Jour. Sci., 1st series, vol. 32, p. 169. (See **Dalmanitis platyleurus.**)

—— **polypleurus** Green, 1838; Am. Jour. Sci., 1st series, vol. 34, p. 380.

—— **quadraticaudatus** Billings, 1865; Pal. Foss., vol. 1, p. 273, fig. 258. Quebec.

—— **rœmingeri** Walcott, 1876; 28th Rept. New York State Mus. Nat. Hist., p. 96. Trenton.

—— *selenurus.* (See **Dalmanites selenurus.**)

—— *stokesi.* (See **Proetus stokesi.**)

—— **susæ** Calvin; MSS.

—— **susæ** Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 236, pl. 5, fig. 3; pl. 10, fig. 8. Trenton.

—— **tetragonocephalus** Green, 1834; Am. Jour. Sci., 1st series, vol. 25, p. 135.

—— **tetragonocephalus** Green, 1835; Suppl. Mon. Tril. N. A., p. 12, cast 38.

—— [*Paradoxides*] **tetragonocephalus** Emmrich, 1839; De Tril., etc., p. 34.

The cast issued with Dr. Green's monograph as No. 38 may be the same species which Dr. Emmons afterwards described as *Atops trilineatus.* It has about sixteen segments in the thorax, also obscure nodes along the axis. The head shows the occular ridges of a *Ptychoparia,* whereas the segments are those characteristic of the *Oleni.* It is too imperfect for generic classification.

—— *trentonensis.* (See **Lichas trentonensis.**)

—— **triangulatus** Whitfield, 1880; Ann. Rept. Geol. Survey Wisconsin, 1879, p. 59. Trenton.

This species is the *Asaphus homalonotoides* of the Final Report, vol. 4, p. 237, pl. 5, fig. 4.

—— ? **trimblii** Green, 1837; Acad. Nat. Sci. Phila., Jour., vol. 7. Niagara.

—— **trimblii** Green, 1837; Am. Jour. Sci., 1st series, vol. 32, p. 348.

—— [*Ogygia?*] **vetustus** Hall, 1847; Pal. N. Y., vol. 1, p. 227, pl. 60, fig. 1. Trenton and Hudson.

—— ? [*Ogygia*] **vetustus** Emmons, 1855; Am. Geology, vol. 1, pt. 2, p. 216, fig. 72.

—— [*Isotelus*] **vigilans** Meek and Worthen, 1870; Proc. Acad. Nat. Sci. Phila., p. 53. Hudson.

—— [*Isotelus*] **vigilans** Meek and Worthen, 1875; Geol. Illinois, vol. 6, p. 491, pl. 23, fig. 6.

—— **wisconsensis** Walcott, 1876; 28th Rept. N. Y. State Mus. Nat. Hist., p. 97. Trenton.

Aspidolites Conrad, 1841; 4th Ann. Rept. Pal. Dept. New York Geol. Survey, p. 48.

Atops Emmons, 1844; Taconic System, p. 20.

Type, *Atops trilineatus* Emmons.

—— **trilineatus** Emmons 1844; Taconic System, p. 20, fig. 1, pl. 2, fig. 3. Taconic.

—— **trilineatus** Emmons, 1847; Nat. Hist. New York, Agriculture, vol. 1, p. 64, fig. 8, pl. 14, fig. 3.

Syn., *Calymene beckii* Hall, 1847; Pal. New York, vol. 1, p. 252, pl. 67, figs. 4 a–4 e (not *Calymene beckii* Green, or *Atops trilineatus* Emmons).

—— **trilineatus** Haldeman, 1848; Am. Jour. Sci., 2d series, vol. 5, p. 107.

—— **trilineatus** Emmons, 1849; Proc. Am. Assoc. Adv. Sci., 1st Meeting, Phila., 1848, pp. 16, 17.

Syn., *Calymene beckii* Fitch, 1849; Trans. Agric. Soc. New York, vol. 9, p. 865 (not *Calymene beckii* Green).

—— **trilineatus** Emmons, 1855; Am. Geology, vol. 1, pt. 2, p. 115, pl. 1, fig. 16.

Syn., *Atops punctatus* Emmons, 1860; Manual Geology, p. 88, fig. 71; also p. 280.

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Atops trilineatus Barrande, 1861; Bull. Soc. Géol. France, 2d series, vol. 18, p. 269, pl. 5, fig. 1.

—— **trilineatus** Barrande, 1861; Bull. Soc. Géol. France, 2d series, vol. 18, p. 271, pl. 5, fig. 3.

—— [*Conocephalites* (*Atops*)] **trilineatus** Ford, 1871; Am. Jour. Sci., 3d series, vol. 2, p. 33.

—— [*Conocephalites*] **trilineatus** Ford, 1873; Am. Jour. Sci., 3d series, vol. 6, p. 135.

—— [*Conocephalites* (*Atops*)] **trilineatus** Ford, 1879; Am. Jour. Sci., 3d series, vol. 9, p. 205.

—— [*Triarthrus*] **trilineatus** Miller, 1877; Catalogue Am. Pal. Foss., p. 223.

—— [*Conocoryphe*] **trilineatus** Ford, 1880; Am. Jour. Sci., 3d series, vol. 19, p. 152.
Syn., *Triarthrus beçki* Walcott, 1879; Trans. Albany Inst., vol. 10, p. 23.

—— [*Ptycoparia*] **trilineatus** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 203, pl. 27, fig. 1 a–c.

—— [*Conocoryphe*] **trilineatus** Walcott, 1887; Am. Jour. Sci., 3d series, vol. 34, p. 197, pl. 1, fig. 7 a, b.

Bailiella Matthew, 1884; Trans. Royal Soc. Canada, vol. 1, p. 124 (used as a subgenus to *Conocoryphe* (*Bailiella*) *Baileyi*).

Barrandia Hall, 1860; 13th Rept. New York State Cab. Nat. Hist., p. 115 (not *Barrandia* McCoy). (See **Olenellus.**)

—— *thompsoni.* (See **Olenellus thompsoni.**)

—— *vermontana.* (See **Olenellus vermontana** and **Mesonasis vermontana.**)

Barrandia McCoy, 1849; Annals Nat. Hist., 2d series, vol. 4, p. 409.
Type, *Barrandia cordai* McCoy.

—— ? **mccoyi** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 96, pl. 12, fig. 5. Pogonip.

Bathynotus Hall, 1860; 13th Rept. New York State Cab. Nat. Hist., p. 117.
Type, *Bathynotus holopyga* Hall.

—— [*Peltura* (*Olenus*)] **holopyga** Hall, 1859; 12th Rept. New York State Cab. Nat. Hist., p. 61, figure.

—— [*Peltura* (*Olenus*)] **holopyga** Hall, 1859; Pal. New York, vol. 3, p. 528, figure.
Syn., *Paradoxides? quadrispinosus* Emmons, 1860; Manual Geology, p. 80, fig. 57.
Paradoxides (*Pagura*) *quadrispinosus* Emmons, 1860; Manual Geology, p. 280, fig. 57.

—— **holopyga** Hall, 1860; 13th Rept. New York State Cab. Nat. Hist., p. 118, figure.

—— **holopyga** Hall, 1861; Geol. Vermont, vol. 1, p. 371, pl. 13, fig. 3.

—— [*Peltura* (*Olenus*)] **holopyga** Barrande, 1861; Bull. Soc. Géol. France, 2d series, vol. 18, p. 278, pl. 5, figs. 9, 10.

—— **holopyga** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 191, pl. 31, figs. 1–1 a. Middle Cambrian.

Bathyurellus Billings, 1865; Pal. Foss., vol. 1, p. 262.

—— **abruptus** Billings, 1865; Pal. Foss., vol. 1, p. 263, fig. 247. Quebec.

—— [*Asaphiscus*] *bradleyi* Meek. (See **Asaphiscus bradleyi.**)

—— **expansus** Billings, 1865; Pal. Foss., vol. 1, p. 318, figs. 306 a, b. Quebec.
Compare *B. nitidus* and *B. marginatus* Billings.

—— **formosus** Billings, 1865; Pal. Foss., vol. 1, p. 265, fig. 250. Quebec.

—— **fraternus** Billings, 1865; Pal. Foss., vol. 1, p. 267, fig. 251. Quebec.
The head of this species may belong to Salter's genus *Stygina.*

—— **litoreus** Billings, 1865; Pal. Foss., vol. 1, p. 320. Quebec.

—— **marginatus** Billings, 1865; Pal. Foss., vol. 1, p. 263, fig. 248. Quebec.
Compare *B. nitidus* and *B. expansus* Billings.

—— **nitidus** Billings, 1865; Pal. Foss., vol. 1, p. 265, fig. 249. Quebec.
On page 320 Mr. Billings says that it may be found necessary to unite *B. nitidus, B. marginatus,* and *B. expansus* into one polymorphic species.

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Bathyurellus rarus Billings, 1865; Pal. Foss., vol. 1, p. 320, no figure. Quebec.
—— [*Dikelocephalus*] **truncatus** Meek, 1873; 6th Ann. Rept. Geol. Survey Territories, p. 465 (no description given).
—— **validus** Billings, 1865; Pal. Foss., vol. 1, p. 268, fig. 252. Quebec.
—— [*Asaphiscus*] *wheeleri*. (See **Asaphiscus wheeleri.**)
Bathyuriscus Meek, 1873; 6th Ann. Rept. U. S. Geol. Survey Territories, p. 484.
—— [*Bathyurus?*] **haydeni** Meek, 1873; 6th Ann. Rept. U. S. Geol. Survey Territories, p. 483. Potsdam.
—— **haydeni** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 215.
—— **howelli** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 216, pl. 30, figs. 2, 2 a. Middle Cambrian.
Syn., *Embolimus rotundatus* (Rominger) Walcott, 1888; Am. Jour. Sci., 3d series, vol. 36, p. 165, referred to *Bathyuriscus howelli.*
—— [*Ogygia*] **producta** Hall and Whitfield, 1877; U. S. Geol. Expl. 40th Par., vol. 4, p. 244, pl. 2, figs. 31–34. Middle Cambrian.
—— [*Ogygia*] **producta** Hall and Whitfield, 1877; U. S. Geol. Expl. 40th Par., vol. 4, p. 245, pl. 2, fig. 35.
—— **producta** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 217, pl. 30, figs. 1, 1 a–c.
Bathyurus Billings, 1859; Canadian Naturalist, vol. 4, p. 364.
Type, *Bathyurus extans* Hall.
—— **amplimarginatus** Billings, 1857; Canadian Naturalist, vol. 4, p. 365, fig. 12 a, b. Calciferous.
—— **amplimarginatus** Billings, 1863; Geol. Canada, p. 122, fig. 41.
—— **amplimarginatus** Billings, 1865; Pal. Foss., vol. 1, p. 352, fig. 341 a.
—— **angelini** Billings, 1859; Canadian Naturalist, vol. 4, p. 467, fig. 37. Chazy.
—— **angelini** Billings, 1863; Geol. Canada, p. 133, fig. 68.
—— **arcuatus** Billings, 1865; Pal. Foss., vol. 1, p. 205, fig. 190. Quebec.
—— **armatus** Billings, 1860; Canadian Naturalist, vol. 5, p. 319, fig. 23.
—— **armatus** Billings, 1865; Pal. Foss., vol. 1, p. 411, fig. 392.
—— **armatus** Walcott, 1879; 32d Rept. New York State Mus. Nat. Hist., p. 131.
—— [*Dorypyge?*] **armatus** Vogdes, Bull. U. S. Geol. Survey No. 63 (this bulletin).
—— **bituberculatus** Billings, 1860; Canadian Naturalist, vol. 5, p. 319, fig. 22; also Geol. Canada, 1863, p. 238, fig. 270. Quebec.
—— **bituberculatus** Billings, 1865; Pal. Foss., vol. 1, p. 410, fig. 391.
If this species is correctly represented by Mr. E. Billings it can not be included within the limits of *Bathyurus*. As we know of no other to which it bears a resemblance, the new generic term of *Lloydia* is proposed, in honor of the first author on Trilobites, Edward Lhwyd. Diagnosis: Glabella tumid and extending to the frontal limb; basal lobes elongate-oval, pointed at both ends, separated from the glabella by shallow, obscure grooves; eyes opposite the mid length of the glabella; thorax unknown.
—— **breviceps** Billings, 1865; Pal. Foss., vol. 1, p. 262, fig. 246. Quebec.
—— **capax** Billings, 1860; Canadian Naturalist, vol. 5, p. 318, fig. 20. Quebec.
—— **capax** Billings, 1863; Geol. Canada, p. 238, fig. 271.
—— **capax** Billings, 1865; Pal. Foss., vol. 1, p. 409, fig. 389.
A similar species was referred by Mr. R. P. Whitfield (Geol. Survey Wisconsin, vol. 4, pl. 4, fig. 6) to *Dicellocephalus.*
—— **caudatus** Billings, 1865; Pal. Foss., vol. 1, p. 261, fig. 245. Quebec.
—— **conicus** Billings, 1859; Canadian Naturalist, vol. 4, p. 366, fig. 12 d. Calciferous.
—— **conicus** Billings, 1863; Geol. Canada, p. 122, fig. 42.
—— **conicus** Billings, 1865; Pal. Foss., vol. 1, p. 352, fig. 341 b.
—— **conicus** Whitfield, 1889; Bull. Am. Mus. Nat. Hist., vol. 2, No. 2, p. 61, pl. 13, figs. 15–21.

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Bathyurus ? congeneris Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 92, pl. 12, fig. 8. Pogonip.

—— **cordai** Billings, 1860; Canadian Naturalist, vol. 5, p. 321, fig. 26. Calciferous.

—— **cordai** Billings, 1863; Geol. Canada, p. 238, fig. 269.

—— **cordai** Billings, 1865; Pal. Foss., vol. 1, p. 259, fig. 242; p. 412, fig. 395.

Compare this species with typical *Solenopleura*.

—— ? **crotalifrons** Dwight, 1884; Am. Jour. Sci., 3d series, vol. 27, p. 253, figs. 4, 4 a, 5, 6. Calciferous.

—— **cybele** Billings, 1859; Canadian Naturalist, vol. 4, p. 366, fig. 12 c. Calciferous.

—— **cybele** Billings, 1863; Geol. Canada, p. 122, fig. 43.

—— **cybele** Billings, 1865; Pal. Foss., vol. 1, p. 352, fig. 341 c.

—— **dubius** Billings, 1860; Canadian Naturalist, vol. 5, p. 319, fig. 21. Quebec.

—— **dubius** Billings, 1865; Pal. Foss., vol. 1, p. 410, fig. 390.

—— [*Asaphus?*] **extans** Hall, 1847; Pal. New York, vol. 1, p. 228, pl. 60, figs. 2 a–c. Trenton.

—— [*Asaphus?*] **extans** Hall, 1850; 3d Rept. New York State Cab. Nat. Hist., p. 174, pl. 3, figs. 1 a–c.

Syn., *Asaphus nodostriatus* Hall, 1850; 3d Rept. New York State Cab. Nat. Hist., p. 175.

—— **extans** Billings, 1863; Geol. Canada, p. 153, fig. 114.

—— **gregarius** Billings, 1865; Pal. Foss., vol. 1, p. 363, fig. 349. Potsdam.

Mr. Walcott (Bull. U. S. Geol. Survey, No. 10, p. 36) refers this species to the genus *Solenopleura* Angelin, and remarks that many of the Cambrian species of the genus *Bathyurus* described in the Canadian reports might be referred to that genus.

—— ? *haydeni*. (See **Bathyuriscus haydeni.**)

—— **longispinus** Walcott, 1876; 28th Rept. N. Y. State Cab. Nat. Hist., p. 94. Trenton.

—— **minganensis** Billings, 1865; Pal. Foss., vol. 1, p. 353. Calciferous.

—— *nero*. (See **Solenopleura nero** (Billings) Walcott.)

—— **oblongus** Billings, 1860; Canadian Naturalist, vol. 5, p. 321, fig. 25. Quebec.

—— **oblongus** Billings, 1865; Pal. Foss., vol. 1, p. 412, fig. 394.

—— **parvulus** Billings, 1861; Geol. Vermont, vol. 2, p. 952, fig. 361.

—— **parvulus** Billings, 1861; Pal. Foss., Bull. Geol. Sur. Canada p. 16, fig. 21. Potsdam.

—— **parvulus** Billings, 1865; Pal. Foss., vol. 1, p. 16, fig. 21.

—— **perplexus** Billings, 1865; Pal. Foss., vol. 1, p. 364, fig. 350. Potsdam.

—— **perspicator** Billings, 1865; Pal. Foss., vol. 1, p. 205, fig. 191. Quebec.

—— **pogonipensis** Hall and Whitfield, 1877; U. S. Geol. Expl. 40th Par., vol. 4, p. 243, pl. 1, figs. 33, 34. Cambrian.

—— **quadratus** Billings, 1860; Canadian Naturalist, vol. 5, p. 321, fig. 27. Quebec.

—— **quadratus** Billings, 1865; Pal. Foss., vol. 1, p. 412, fig. 396.

—— **saffordi** Billings, 1860; Canadian Naturalist, vol. 5, p. 321, fig. 24. Quebec.

—— **saffordi** Billings, 1865; Pal. Foss., vol. 1, p. 259, fig. 341; p. 411, fig. 393.

—— **seelyi** Whitfield, 1886; Bull. Am. Mus. Nat. Hist., New York, vol. 1, No. 8, p. 339, pl. 33, figs. 12–18. Birdseye.

—— **seelyi** Whitfield, 1889; Bull. Am. Mus. Nat. Hist., New York, vol. 2, No. 2, p. 62, pl. 13, figs. 8–14.

—— **senectus** Billings, 1861; Bull. Geol. Sur. Canada, p. 16. Potsdam.

—— **senectus** Billings, 1861; Geol. Vermont, vol. 2, p. 953, figs. 359, 360.

—— **senectus** Billings, 1863; Geol. Canada, p. 286, figs. 298 a, b; Pal. Foss., vol. 1, p. 16 (1865), figs. 19, 20.

Referred to *Protypus senectus* Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 213, pl. 31, figs. 2, 2 a–c.

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Bathyurus serratus Meek, 1873; 6th Ann. Rept. U. S. Geol. Survey Territories, p. 480. Potsdam.
—— ? **simillimus** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 93, pl. 12, fig. 11. Pogonip.
—— **smithi** Billings, 1863; Geol. Canada, p. 153, fig. 115. Trenton.
—— **smithi** Billings, 1865; Pal. Foss., vol. 1, p. 56.
—— **solitaricus** Billings, 1865; Pal. Foss., vol. 1, p. 362. Quebec.
—— [*Acidaspis*] **spiniger** Hall, 1847; Pal. New York, vol. 1, p. 241, pl. 64, fig. 5. Trenton.
—— **stonemani** Vogdes, 1884; 12th Ann. Rept. Geol. Nat. Hist. Minnesota, p. 8. Trenton.
—— **strenuus** Billings, 1865; Pal. Foss., vol. 1, p. 204, fig. 188. Quebec.
—— **taurifrons** Dwight, 1884; Am. Jour. Sci., 3d series, vol. 27, p. 252, pl. 7, figs. 1–3. Calciferous.
—— **timon** Billings, 1865; Pal. Foss., vol. 1, p. 261, fig. 244. Quebec.
—— ? **tuberculatus** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 12, fig. 9. Pogonip.
—— **vetula** Billings, 1865; Pal. Foss., vol. 1, p. 365. Potsdam.
—— [*Agraulos* (*Bathyurus?*)] **woosteri** Whitfield, 1878; Ann. Rept. Geol. Survey Wisconsin, p. 56. Potsdam.
—— [*Agraulos* (*Bathyurus?*)] **woosteri** Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 189, pl. 1, figs. 19–21.

Bohemilla Barrande, 1872; Syst. Sil. Bohême, Suppl., vol. 1, p. 137.
Type, *Bohemilla stupenda* Barrande.

Brongniartia Eaton, Am. Jour. Sci., 1st series, vol. 22, p. 166, and Geol. Text-Book, p. 32 (Syn., *Asaphus* in part), not *Brongniartia* Salter (subgenus *Homalonotus*).
—— *carcinoides* Eaton. (See **Triarthrus becki.**)
—— *isoletea.* (See **Asaphus platycephalus.**)
—— *platycephus* Eaton. (See **Homalonotus delphinocephalus.**)

Brachymetopus McCoy, 1847; Ann. Nat. Hist., vol. 20, p. 220.
Type, *Brachymetopus maccoyi* Portlock.
—— [*Phillipsia* (*Griffithides*)] **lodiensis** Meek, 1875; Pal. Ohio, vol. 2, p. 323, pl. 18, fig. 3. Waverly.
—— **lodiensis** Vogdes, 1888; Annals New York Acad. Sci., vol. 4, p. 102.
—— [*Phillipsia* (*Brachymetopus*)] *ornata* Hall. (See **Cyphaspis ornata.**)

Bronteus Goldfuss, 1839; Beiträge Petrefactenkunde, Nova Acta Physico-Med., vol. 19, p. 360, pl. 33, fig. 3.
Type, *Bronteus flabellifera* Goldfuss.
Syn., *Goldius* De Koninck, 1841; Mém. Crust. Foss. Belgique, p. 5.
—— **acamas** Hall, 1865; 20th Rept. New York State Cab. Nat. Hist., p. 332, pl. 21, figs. 19, 20. Niagara.
—— **acamas** Hall, 1870; 20th Rept. New York State Cab. Nat. Hist., p. 422, pl. 21, figs. 19, 20 (rev. ed.).
—— **barrandi** Hall, 1859; Pal. New York, vol. 3, p. 350, pl. 63, figs. 1–4. Lower Helderberg.
—— **canadensis** Logan, 1844; Geol. Canada, p. 54, 2 figs. Lower Helderberg.
—— **insularis** Billings, 1866; Catalogue Sil. Foss. Anticosti, p. 66.
—— **laphami** Whitfield, 1878; Ann. Rept. Geol. Survey Wisconsin (1877), p. 88. Niagara.
—— **laphami** Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 310, pl. 22, figs. 1–4.
—— **lunatus** Billings, 1857; Geol. Canada, p. 338. Trenton.
—— **lunatus** Billings, 1863; Geol. Canada, p. 188, fig. 187.
—— ? **niagarensis** Hall, 1852; Pal. New York, vol. 3, p. 314, pl. 70, fig. 3. Niagara.

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Bronteus occasus Winchell and Marcy, 1866; Mem. Boston Soc. Nat. Hist., vol. 1, p. 104, pl. 3, fig. 12. Niagara.

—— **occasus** (Winchell and Marcy) Hall, 1867; 20th Rept. New York State Cab. Nat. Hist., p. 400.

—— **pompilius** Billings, 1863; Proc. Portland Soc. Nat. Hist., p. 123, pl. 1, fig. 25. Upper Silurian.

—— **tullius** Hall, 1888; Pal. New York, vol. 7, p. 12, pl. 8, figs. 34–36. Hamilton.

Bumastus Murchison, 1839; Sil. Syst., p. 656. Subgenus, *Illænus*.

Calymene Brongniart, 1822; Crust. Fos., p. 9.

Type, *Calymene tuberculata* Bünnich, 1781.

Syn., *Prionocheilus*, Rouault, Bull. Soc. Géol. France, vol. 4, 1846, p. 309.

—— *anchiops*. (See **Dalmanites anchiops**.)

—— *beckii*. (See **Triarthrus becki**.)

—— **blumenbachi** Brongniart, 1822; Crust. Foss., p. 11, pl. 1, figs. 1 a–d.

—— **blumenbachi** Barrande, 1852; Syst. Sil. Bohême, pls. 19 and 45.

—— **blumenbachi** Salter, 1863; Mon. Brit. Trilobites, pl. 8, figs. 7–11, 13–16; pl. 9, fig. 1.

This species should take the older name of *Calymene tuberculata* Bünnich.

—— **blumenbachi** (Green) not Brong., Mon. Tril. N. A., p. 28, cast 1.

—— **blumenbachi** ? Foerste, 1885; Bull. Denison Univ., vol. 1, p. 100, pl. 13, fig. 25.

—— *bucklandi*. (See **Ceraurus pleurexanthus** Green.)

—— *bufo*. (See **Phacops bufo** Green.)

—— *bufo* var. *rana*. (See **Phacops rana** Green.)

—— **callicephala** Green, 1832; Mon. Tril. N. A., p. 30, cast 2.

—— **callicephala** Burmeister, 1843; Org. Trilobiten, p. 83, pl. 2, figs. 9–10 (Ray Soc. ed.).

—— **callicephala** Miller, 1882; Jour. Cincinnati Soc. Nat. Hist., vol. 5, p. 117, pl. 5, fig. 8.

The cast of this species (from a dark yellowish limestone of Hampshire County, Virginia), issued with Dr. Green's monograph, exhibits a *Calymene* with a broad frontal margin. The other specimens referred to by Dr. Green from Ohio and Indiana are species of the well-known *Calymene senaria* Conrad.

—— **camerata** Conrad, 1842; Jour. Acad. Nat. Sci. Phila., vol. 8, p. 278. Niagara.

—— **camerata** Hall, 1852; Pal. New York, vol. 2, p. 337, pl. 78, figs. 10 a–f.

—— **christyi** Hall, 1860; 13th Rept. New York State Cab. Nat. Hist., p. 119. Hudson.

—— **christyi** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., pl. 10, figs. 1, 2, and 5.

—— **christyi** Hall and Whitfield, 1875; Pal. Ohio, vol. 2, p. 107, pl. 4, figs. 13–15.

—— **christyi** Miller, 1874; Cincinnati Quart. Jour. Sci., vol. 1, p. 141.

—— [*Hemicrypturis*] **clintoni** Vanuxem, 1842; Geol. New York, 3d Geol. Dist., p. 79, fig. 3; also p. 80. Clinton.

—— **clintoni** Hall, 1852; Pal. New York, vol. 2, p. 298, pl. 66 a, figs. 5 a–d.

—— **clintoni** Rogers, 1858; Geol. Survey Pennsylvania, vol. 2, p. 823, fig. 637.

—— **clintoni** Vogdes, 1880; Proc. Acad. Nat. Sci. Phila., p. 178, figs. 3, 4 (not fig. 3).

—— *clintoni* Vogdes, 1886; Des. New Species Foss. Crust. Clinton Group, p. 5, figs. 3, 4. (See **Calymene vogdesii** Foerste.)

—— **conradi** Emmons, 1855; Am. Geology, vol. 1, pt. 2, p. 236. Hudson.

—— *crassimarginata*. (See **Proetus crassimarginata**.)

—— *diops* Green, 1832; Mon. Tril. N. A., p. 37, pl. 1, fig. 2, cast 8 (*Proetus diops*).

—— *macrophthalma* Green, 1832; Mon. Tril. N. A., p. 39, cast 9. (See **Phacops bufo**.)

—— **mamillata** Hall, 1861; Geol. Wisconsin, p. 50. Trenton.

—— **mamillata** Hall, 1862; Geol. Wisconsin, vol. 1, p. 432, figs. 1, 2.

—— *marginatus*. (See **Proetus marginatus**.)

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Calymene microps Green, 1832; Mon. Tril. N. A., p. 34, cast 6.
—— **multicosta** Hall, 1847; Pal. New York, vol. 1, p. 228, pl. 60, fig. 3. Trenton.
—— **nasuta** Ulrich, 1879; Jour. Cincinnati Soc. Nat. Hist., vol. 2, p. 131, fig. 3. Niagara.
—— **niagarensis** Hall, 1843; Geol. New York, 4th Dist., p. 102, fig. 3 (on p. 101). Niagara.
—— *blumenbachii* var. **niagarensis** Hall, 1852; Pal. New York, vol. 2, p. 307, pl. 67, figs. 11, 12.
—— *blumenbachii* Roemer, 1860; Sil. Fauna W. Tenn., p. 79, pl. 5, fig. 22.
—— **niagarensis** Hall and Whitfield, 1875; Pal. Ohio, vol. 2, p. 153, pl. 7, figs. 14, 15.
—— **niagarensis** Hall; 20th Rept. New York State Cab. Nat. Hist., p. 334; revised edition, p. 425.
—— **niagarensis** Hall, 1876; Illus. Devon. Foss. Crustacea, pl. 1, fig. 10.
—— **niagarensis** Hall, 1879; 28th Rept. N. Y. State Mus. Nat. Hist., p. 187, pl. 22, figs. 8–15.
—— **niagarensis** Hall, 1883; 11th Ann. Rept. Geol. Nat. Hist. Indiana, 1881, p. 331. pl. 34, figs. 8–15.
Compare *C. brevicapitata* (Portlock) McCoy; Brit. Pal. Foss., pl. 1 F, fig. 4.
—— *nupera.* (See **Phacops nupera.**)
—— *odontocephala.* (Syn., *Dalmanites selenus.*)
—— **phlyctainodes** Green, 1837; Am. Jour. Sci., 1st series, vol. 32, p. 167.
Dr. Green compares this species with *Encrinurus variolaris.*
—— **platys** Green, 1832; Mon. Tril. N. A., p. 32, casts 4, 5. Upper Helderberg.
—— **platys** Hall, 1861; Des. New Species Foss., p. 54.
—— **platys** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 82.
—— **platys** Hall, 1876; Illus. Devon. Foss. Crustacea, pl. 1, figs. 1–9.
—— **platys** Hall, 1888; Pal. New York, vol. 7, p. 1, pl. 1, figs. 1–9; pl. 25, figs. 1, 2.
—— *rana.* (See **Phacops rana** Green.)
—— **rostrata** Vogdes, 1879; Am. Jour. Sci., 3d series, vol. 18, p. 477. Clinton.
—— **rostrata** Vogdes, 1880; Proc. Acad. Nat. Sci. Phila., p. 176, figs. 1, 2.
—— **rostrata** Vogdes, 1886; Des. New Species Foss. Crust. Clinton Group, p. 2, figs. 1, 2.
—— *rowi.* (See **Phacops rowi** Green.)
—— **rugosa** Shumard, 1855; 1st and 2d Repts. Geol. Missouri, p. 200, pl. B, fig. 14. Lower Helderberg.
—— *selenecephala.* (See **Calymene senaria** Conrad.)
—— **senaria** Conrad, 1841; 4th Ann. Rept. Pal. Dept. New York Geol. Survey, p. 49. Trenton.
—— **senaria** Emmons, 1842; Geol. New York, 2d Geol. Dist., p. 390, fig. 2.
Syn., *selenecephala* Green, 1832; Mon. Tril. N. A., p. 31, cast 3.
blumenbachii Green, 1832; Mon. Tril. N. A., p. 28, cast 1. (Not of Brongniart.)
callicephala Green, 1832; Mon. Tril. N. A., p. 31. (Specimens from Ohio and Indiana only.)
brevicapitata Salter, 1848; Mem. Geol. Surv. United Kingdom, vol. 2, p. 341, pl. 11, figs. 1, 2. (Not of Portlock, 1843; Geol. Rept. Londonderry, etc., p. 286, pl. 3, fig. 3.)
brevicapitata (Portlock) Salter; Mem. Geol. Surv. United Kingdom, vol. 3, pl. 17, figs. 11, 12. (Not of Portlock.)
forcipata (McCoy) Salter; Palæon. Soc. London, vol. 17, p. 97. (Not of McCoy, Sil. Foss. Ireland, pl. 4, fig. 14.)
—— **senaria** Emmons, 1855; Am. Geology, vol. 1, pt. 2, p. 213, pl. 16, fig. 9.
—— **senaria** Hall, 1847; Pal. New York, vol. 1, p. 238, pl. 64, figs. 3 a–n.

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Calymene [*blumenbachii*] var. **senaria** Hall, 1852; Pal. New York, vol. 2, p. 299, pl. 66 a, figs. 6 a–e. Clinton.

—— **senaria** var. **blumenbachii** Salter, 1865; Mon. Brit. Tril., p. 97, pl. 9, figs. 6–10 (not figs. 7, 8, *Calymene brevicapitata* Portlock).

—— **senaria** Meek, Pal. Ohio, vol. 1, p. 173, pl. 14, figs. 14 a–f.

—— **senaria** Miller, 1874; Cincinnati Quart. Jour. Sci., vol. 1, p. 140.

Syn., *callicephala* (Green) Miller, 1877; Catalogue Am. Pal. Foss., p. 213.

—— **senaria** White, 1880; 2d Ann. Rept. Dept. Statistics Geol. Indiana, p. 493, pl. 2, figs. 1, 2.

Syn., *callicephala* (Green) Miller, 1882; Jour. Cincinnati Soc. Nat. Hist., vol. 5, p. 117, pl. 5, fig. 8.

—— **senaria** Walcott, 1887; Notes on Some Sections of Trilobites, pl. 1.

—— **senaria** Walcott, 1884; Science, March 7, 1884, vol. 3, p. 201, figs. 2, 3.

—— **spinifera** Conrad, 1842; Jour. Acad. Nat. Sci. Phila., vol. 8, p. 277.

Compare *Cyphaspis girardeauensis*.

—— *trisulcata*. (See **Phacops trisulcata**.)

—— **vogdesii** Foerste, 1887; Bull. Denison Univ., vol. 2, p. 95, pl. 8, figs. 12–16. Clinton.

—— ? *blumenbachi* Foerste, 1886; Bull. Denison Univ., vol. 1, p. 190, pl. 13, fig. 24.

Syn., *clintoni* Vogdes, 1882; Proc. Acad. Nat. Sci. Phila., p. 178, fig. 3 (not fig. 4).

clintoni Vogdes, 1886; Des. New Species Foss. Crust. Clinton Group, p. 5, fig. 3 (not fig. 4).

Ceratocephala Warder, 1838. (See **Acidaspis**.)

—— *ceralepta* Anthony. (See **Acidaspis ceralepta**.)

—— **goniata** Warder, 1838; Am. Jour. Sc., 1st series, vol. 34, p. 378, figure.

Ceratolichas Hall, 1888; Pal. New York, vol. 7, p. xl. Subgenus *Lichas*.

Ceraurus Green, 1832; Monthly Am. Jour. Geol., vol. 1, p. 560, pl., fig. 6; Mon. Tril. N. A., p. 83, cast 33, pl., fig. 10.

Ceraurus Hall, 1847; Pal. New York, vol. 1, p. 242.

Syn., *Otarion* (in part) Zenker, 1833; Beiträge Nat. Urwelt, p. 44.

Arges (in part) Goldfuss, 1843; Neues Jahrbuch für Mineral., p. 5.

Cyphaspis (in part) Burmeister, 1843, Org. Trilobiten, p. 104.

Amphion (in part) Portlock, 1843; Geol. Survey Londonderry, etc., p. 272.

Cyphaspis (in part) McCoy, 1846; Sil. Foss. Ireland, p. 44.

Cheirurus Beyrich, 1846; Unters. Trilobiten, etc. II, p. 3.

Eccoptochile Corda, 1847; Prodr., p. 245.

Actinopeltes Corda, 1847; Prodr., p. 247.

Crotalocephalus Salter, 1853; Mem. Geol. Survey United Kingdom, decade 7, pl. 2, p. 10.

Cyrtometopus Angelin, 1854; Pal. Scand., p. 32.

Sphærocoryphe Angelin, 1854; Pal. Scand., p. 65.

Pseudophæroxochus Schmidt, 1881; Rev. Baltic Sil. Tril., p. 130.

Nieszkowskia Schmidt, 1881; Rev. Baltic Sil. Tril., p. 130.

Type, *Ceraurus pleurexanthemus* Green.

—— [*Cheirurus*] **appollo** Billings, 1860; Canadian Naturalist, vol. 5, p. 322, fig. 28. Quebec.

—— [*Cheirurus*] **appollo** Billings, 1865; Pal. Foss., vol. 1, p. 413, fig. 397.

—— [*Cheirurus*] *bimucronatus* (Murch.) Roemer, Die sil. Fauna W. Tenn., p. 80, pl. 5, fig. 19, not of Murchison. (See **Ceraurus niagarensis** Hall.)

—— *crosotus* Lock. (See **Acidaspis crosotus**.)

—— [*Cheirurus*] **eryx** Billings, 1860; Canadian Naturalist, vol. 5, p. 322, fig. 30. Quebec.

—— [*Cheirurus*] **eryx** Billings, 1865; Pal. Foss., vol. 1, p. 413, fig. 399.

—— [*Cheirurus*] **glaucus** Billings, 1865; Pal. Foss., vol. 1, p. 323, fig. 308. Quebec.

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Ceraurus [*Cheirurus*] **icarus** Billings, 1860; Canadian Naturalist, vol. 5, p. 67, fig. 14. Hudson.

—— [*Cheirurus*] **icarus** Billings, 1863; Geol. Canada, p. 219, fig. 231.

—— **icarus** Meek, 1873; Pal. Ohio, vol. 1, p. 162, pl. 14, fig. 11 a, b, c.

—— **icarus** Miller, 1874; Cincinnati Quart. Jour. Sci., vol. 1, p. 133.

—— [*Cheirurus*] **insignis** (Beyrich) Hall, 1852; Pal. New York, vol. 2, p. 300, also p. 306, pl. 67, figs. 9, 10.

Not of Beyrich, 1845; Ueber einige böhm. Tril., p. 12, pl. 1, fig. 1,

—— *insignis*. (See **Ceraurus niagarensis** Hall.)

—— **mercurius** Billings, 1865; Pal. Foss., vol. 1, p. 285, fig. 272. Quebec.

—— **niagarensis** Hall, 1867; 20th Rept. New York State Cab. Nat. Hist., p. 376, pl. 21, fig. 10.

—— **niagarensis** Hall, 1870; 20th Rept. New York State Cab. Nat. Hist. (2d ed.), p. 427, pl. 21, figs. 10, 11.

Syn., *Sphærexochus romingeri?* Hall; Doc. Ed. 28th Rept. New York State Mus. Nat. Hist.

Explanation of pl. 32, fig. 16 (erroneous reference).

—— [*Cheirurus*] **niagarensis** Hall, 1879; 28th Rept. New York State Mus. Nat. Hist., p. 189, pl. 32, fig. 16.

Syn., *Cheirurus bimucronatus* (Murch.) Roemer; Die sil. Fauna W. Tenn., p. 80, pl. 5, fig. 19.

—— **niagarensis** Hall, 1882; 12th Ann. Rept. Geol. Nat. Hist. Indiana, 1881, p. 335, pl. 34, fig. 16; pl. 33, fig. 10.

—— [*Cheirurus*] **numitor** Billings, 1866; Catalogue Sil. Foss. Anticosti, p. 27, fig. 11. Hudson.

—— [*Cheirurus*] **nuperus** Billings, 1866; Catalogue Sil. Foss. Anticosti, p. 61, fig. 20. Anticosti.

—— [*Cheirurus*] **perforator** Billings, 1865; Pal. Foss., vol. 1, p. 287, fig. 275. Quebec.

—— **pleurexanthemus** Green, 1832; Monthly Am. Jour. Geol., vol. 1, p. 560, pl., fig. 10. Trenton and Hudson.

—— **pleurexanthemus** Green, 1832; Mon. Tril. N. A., p. 84, fig. 10, pl. 1, cast 33.

Syn., *Calymene bucklandi* Anthony, 1838; Am. Jour. Sci., 1st series, vol. 36, p. 106, figs. 1, 2.

—— **pleurexanthemus** Hall, 1847; Pal. New York, vol. 1, p. 242, pl. 65, figs. 1 a–n; pl. 66, figs. 1, 1 h.

—— **pleurexanthemus** Emmons, 1855; Am. Geology, vol. 1, p. 217, pl. 15, figs. 1 a–k.

—— [*Cheirurus*] **pleurexanthemus** Billings, 1863; Geol. Canada, p. 188, fig. 188.

—— **pleurexanthemus** Miller, 1874; Cincinnati Quart. Jour. Sci., vol. 1, p. 132.

—— **pleurexanthemus** Walcott, 1875; Annals Nat. Hist. New York, vol. 11, p. 155, pl. 11.

—— **pleurexanthemus** Walcott, 1881; Bull. Mus. Comp. Zool. Harvard Coll., vol. 8, p. 211, pl. 5, figs. 1–6.

—— [*Cheirurus*] **polydorus** Billings, 1865; Pal. Foss., vol. 1, p. 286, fig. 274. Quebec.

—— [*Cheirurus*] **pompilius** Billings, 1865; Pal. Foss., vol. 1, p. 181, fig. 162. Chazy and Hudson.

—— [*Cheirurus*] **prolificus** Billings, 1865; Pal. Foss., vol. 1, p. 285, fig. 273; p. 325, fig. 341. Quebec.

—— ? **pustulosa** Hall, 1847; Pal. New York, vol. 1, p. 246, pl. 61, fig. 2 a–h. Trenton.

—— **rarus** Walcott, 1877; Advanced sheets 31st Rept. New York State Mus. Nat. Hist., p. 15. Trenton.

—— **rarus** Walcott, 1879; 31st Rept. New York State Mus. Nat. Hist., p. 68.

—— [*Cheirurus*] **satyrus** Billings, 1865; Pal. Foss., vol. 1, p. 324, fig. 309. Chazy.

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Ceraurus [*Cheirurus*] **sol** Billings, 1865; Pal. Foss., vol. 1, p. 288, fig. 276. Quebec.
—— [*Cheirurus*] **solitarius** Billings, 1865; Pal. Foss., vol. 1, p. 206. Quebec.
—— [*Cheirurus*] **tarquinius** Billings, 1863; Proc. Portland Soc. Nat. Hist., vol. 1, p. 121, pl. 1, fig. 22. Upper Silurian.
—— *vigilans*. (See **Encrinurus vigilans**.)
—— [*Cheirurus*] **vulcanus** Billings, 1865; Pal. Foss., vol. 1, p. 284, fig. 27; p. 324, fig. 310. Quebec.
Chariocephalus Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 175.
Type, *Chariocephalus whitfieldi* Hall.
—— **tumifrons** Hall and Whitfield, 1877; U. S. Geol. Expl. 40th Par., vol. 4, p. 224, pl. 2, figs. 38, 39. Potsdam.
—— ? **tumifrons** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 61, pl. 10, fig. 16.
—— **whitfieldi** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 175, pl. 6, figs. 49–53; pl. 10, fig. 20. Potsdam.
Chasmops McCoy, 1849; Annals Mag. Nat. Hist., 2d series, vol. 4, p. 403. (See **Dalmanites** [*Chasmops*] **anchiops, anchiops** var. **armatus, anchiops** var. **sobrinus, D.** [*Chasmops*] **calypso, D.** [*Chasmops*] **erina, D.** [*Chasmops*] **macrops**.
—— [*Dalmanites*] **troosti** Safford, 1869; Geol. Tennessee, p. 290. Trenton.
—— **troosti** Safford and Vogdes, 1889; Proc. Acad. Nat. Sci. Phila., p. 167, figure.
Conocephalus Zenker, 1833; Beiträge Nat. Urwelt, p. 48.
Conocephalites Barrande, 1852; Syst. Sil. Bohême, vol. 1, p. 415.
For species previously classed under these genera, see **Conocoryphe, Ptychoparia,** and **Crepicephalus**.
Conocoryphe Corda, 1847; Prodr., p. 139, pl. 2, fig. 10.
Type, *Conocoryphe sulzeri* Schlotheim.
—— [*Conocephalites*] **baileyi** Hartt, 1868; Acadian Geology, p. 645 (3d ed.). St. John.
—— **baileyi** Matthew, 1884; Trans. Royal Soc. Canada, vol. 1, p. 111, pl. 1, figs. 22–27.
—— [*Bailiella*] **baileyi** Matthew, 1884; Trans. Royal Soc. Canada, vol. 1, pl. 1, fig. 22.
—— [*Salteria*] **baileyi** Walcott, 1884; Bull. U. S. Geol. Survey, No. 10, p. 32, pl. 4, figs. 3, 3 a; pl. 5, figs. 7, 7 a.
The author herein proposed the subgenus *Salteria* (corrected to *Bailiella*) for *Erinnys* Salter, a preoccupied generic name; the same is true of *Salteria*, used for a genus of fossil Crustacea.
—— [*Conocephalites*] **calcifera** Walcott, 1879; 32d Rept. New York State Mus. Nat. Hist., p. 129. Calciferous.
—— [*Conocephalites*] **cordilleræ** Rominger, 1887; Proc. Acad. Nat. Sci. Phila., p. 17, pl. 1, fig. 7. Cambrian.
—— **elegans** Hartt, 1868; Acadian Geol. (3d ed.), p. 650. St. John.
—— **elegans** Walcott, 1884; Bull. U. S. Geol. Survey, No. 10, p. 33, pl. 4, figs. 2, 2 a, b.
—— *gemini-spinosus* Hartt. (See **Conocoryphe matthewi**.)
—— [*Conocephalites*] **hartti** Walcott, 1879; 32d Rept. New York State Mus. Nat. Hist., p. 131. Calciferous.
—— [*Conocephalites*] **matthewi** Hartt, 1868; Acadian Geology, p. 646, fig. 224. St. John.
—— [*Conocephalites*] **matthewi** Matthew, 1884; Trans. Royal Soc. Canada, vol. 1, p. 103, pl., figs. 6–21.
Syn., *Harttia matthewi* Walcott, 1884; Bull. U. S. Geol. Survey, No. 10, p. 19, pl. 1, fig. 3.
—— **matthewi** Walcott, 1884; Bull. U. S. Geol. Survey, No. 10, p. 28, pl. 4, figs. 1, 1 a, b.
—— [*Conocephalites*] **optatus** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 122, pl. 5 a, fig. 7. Potsdam.
—— [*Conocephalites*] *trilineatus*. (See **Atops trilineatus** Emmons.)

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Conocoryphe [*Conocoryphe*] *trilineatus*. (See **Atops trilineatus** Emmons.)

—— [*Bailella*] **walcotti** Matthew, 1884; Trans. Royal Soc. Canada, vol. 1, p. 119, pl. 1, figs. 36–36 b. St. John.

—— **walcotti** Walcott, 1884; Bull. U. S. Geol. Survey, No. 10, p. 30.

Conolichas Dames, 1877; Zeitschr. Deutsch. geol. Gesell., Berlin, 1877, p. 806. *Conolichas*, subgenus *Lichas* Hall, 1888; Pal. New York, vol. 7, p. xxxix.

Coronura Hall, 1888; Pal. New York, vol. 7, p. xxxii. (See **Dalmanites** [*Coronura*] **aspectans**, **D.** [*Coronura*] **myrmecophorus**, and **D.** [*Coronura*] **emarginatus**.)

Corycephalus Hall, 1888; Pal. New York, vol 7, p. xxxiv. (See **Dalmanites** [*Corycephalus*] **regalis**, **D.** [*Corycephalus*] **pygmæus**, and **D.** [*Corycephalus*] **dentatus**.)

Crepicephalus Owen, 1852; Rept. Geol. Survey Wisconsin, Iowa, and Minnesota, p. 576.

There is hardly a question that Dr. D. D. Owen had before him when he wrote the description of his genus *Crepicephalus* a true *Ptychoparia*. He remarks: "The rather flat, slipper-shaped glabella is tapering and slightly acuminated anteriorly, with a faint ridge on the median line; two small and very superficial depressions and a posterior faint furrow very partially divide the glabella. The facial sutures run nearly parallel to the margin of the glabella and join a thickened, cord-like anterior narrow border, inclosing a convex area, narrower in front than at the sides. Oblique plications can sometimes be traced on the check-plate in advance of the eye, converging towards the apex of the glabella." He refers the following figures to the genus: Plate 1, fig. 8, *Crepicephalus?*, pygidium from the Miniskah Trilobite grit. Plate 1, fig. 13, *Crepicephalus? wisconensis* (n. s.), part of cephalothorax and a portion of the cephalic shield of *D. granulosus?*. Plate 1 a, fig. 10, glabella of *Crepicephalus* n. g., near Miniskah. Plate 1 a, fig. 14, pygidium of *Crepicephalus? miniscaenis* n. s., from Miniskah grits. Plate 1 a, fig. 16, pygidium and portion of *Crepicephalus* (?) and portions of cephalothorax of that genus, from the Miniskah Trilobite grit. Plate 1 a, fig. 18, glabella of *Crepicephalus*, near Miniskah, Mississippi River.

—— [*Bathyurus?*] *angulatus* Hall and Whitfield. (See **Ptychoparia angulatus**.)

—— [*Loganellus*] *anytus* Hall and Whitfield. (See **Ptychoparia anytus**.)

—— [*Loganellus*] *centralis* Whitfield. (See **Ptychoparia oweni**.)

—— **gibbsi** Whitfield, 1880; Ann. Rept. Geol. Survey Wisconsin, 1879, p. 50. Potsdam.

—— **gibbsi** Whitfield, 1880; Geol. Wisconsin, vol. 2, p. 67.

—— **gibbsi** Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 184, pl. 10, figs. 12, 13.

—— [*Loganellus*] *granulosa* Hall and Whitfield. (See **Ptychoparia granulosa**.)

—— [*Loganellus*] *haguei*. (See **Lisostracus haguei** and **Ptychoparia haguei**.)

—— [*Loganellus*] *maculosus* Hall and Whitfield. (See **Ptychoparia maculosus**.)

—— [*Loganellus*] *montanensis* Whitfield. (See **Ptychoparia montanensis**.)

—— [*Loganellus*] *nitidens* Hall and Whitfield. (See **Ptychoparia nitidens**.)

—— **onustus** Whitfield, 1878; Ann. Rept. Geol. Survey Wisconsin, 1877, p. 53. Potsdam.

—— **onustus** Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 182, pl. 1, figs. 22, 23.

—— *oweni*. (See **Agraulos oweni** and **Ptychoparia oweni**.)

—— [*Loganellus*] *planus* Whitfield. (See **Ptychoparia planus**.)

—— [*Loganellus*] *quadrans* Hall and Whitfield. (See **Ptychoparia quadrans**.)

—— [*Loganellus*] *simulator* Hall and Whitfield. (See **Ptychoparia nitidens**.)

—— [*Loganellus*] *unisulcatus* Hall and Whitfield. (See **Ptychoparia unisulcatus**.)

—— ? *wisconsensis* Owen. (See **Anomocare wisconsensis**.)

Crepicephalus Walcott, 1884; Bull. U. S. Geol. Survey, No. 10, p. 35.

Type, *Dikelocephalus? iowensis* Owen.

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Crepicephalus augusta Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 208, pl. 28, figs. 2, 2 a, b. Middle Cambrian.

—— [*Dikelocephalus?*] **iowensis** Owen, 1852; Rept. Geol. Wisconsin, Iowa, and Minnesota, p. 575, pl. 1, fig. 4; pl. 1 a, fig. 13. Potsdam.

Undetermined Trilobite Owen, 1848; Rept. Geol. Reconnoissance Chippewa Land Dist., p. 14, pl. 7, fig. 1.

—— [*Conocephalites*] **iowensis** Shumard, 1863; Trans. Acad. Sci. St. Louis, vol. 2, p. 102.

—— [*Conocephalites*] **iowensis** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 162, pl. 7, fig. 33; pl. 8, figs. 10–12 and 30.

—— **iowensis** Walcott, 1884; Bull. U. S. Geol. Survey, No. 10, p. 36.

—— **iowensis** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 207.

—— **liliana** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 209, pl. 28, figs. 3, 3 a, c. Middle Cambrian.

Cryphæus Green, 1837; Am. Jour. Sci., 1st series, vol. 32, p. 343.

Type, *Cryphæus boothi* Green.

—— [*Dalmanites* (*Cryphæus*)] **barrisi** Hall, 1888; Pal. New York, vol. 7, p. 48, pl. 16 a, fig. 18. Hamilton.

—— **boothi** Green, 1837; Am. Jour. Sci., 1st series, vol. 32, p. 343, figure. Hamilton.

Syn., *Cryphæus greeni* Conrad, 1839; 2d Ann. Rept. Pal. Dept. New York Geol. Survey, p. 66.

Cryphæus calliteles Conrad, 1839; 2d Ann. Rept. Pal. Dept. New York Geol. Survey, p. 62.

Asaphus halli Conrad, 1840; 3d Ann. Rept. Pal. Dept. New York Geol. Survey, p. 204.

Cryphæus calliteles Hall, 1843; Geol. New York, pt. 4, p. 201.

Cryphæus calliteles De Verneuil, 1850; Bull. Soc. Géol. France, 2d series, vol. 7, p. 164, pl. 1, fig. 3.

Phacops pectinatus F. A. Roemer, 1850; Beiträge zur Kenntn. Harzgeb., p. 62, pl. 9, fig. 27.

Dalmania calliteles Emmons, 1860; Manual Geology, p. 138, fig. 124 (7).

—— [*Dalmania*] **boothi** Hall, 1861; Des. New Species of Fossils, p. 63.

—— [*Dalmania*] **boothi** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 91.

—— [*Dalmanites*] **boothi** Hall, 1876; Illus. Devonian Foss., pl. 16, figs. 1–6, 9–11, 13, 15, 16.

Syn., *Cryphæus stellifer* Kayser, 1878; Abhandl. geol. Specialkarte Pr., vol. 2, pt. 4, p. 33, (in part).

Cryphæus laciniatus Kayser, 1878; *idem.*, p. 34.

—— [*Dalmanites* (*Cryphæus*)] **boothi** Hall, 1888; Pal. New York, vol. 7, p. 42, pl. 16, figs. 1–4; pl. 16 a, figs. 3–8.

—— **callitelus** Green, 1837; Am. Jour. Sci., 1st series, vol. 32, p. 346. Hamilton.

—— [*Dalmanites*] **boothi** Hall, 1876; Illus. Devonian Foss., pl. 16, figs. 7, 8, 12, 14.

—— (?) **callitelus** Kayser, 1878; Abhandl. geol. Specialkarte Pr., vol. 2, pt. 4, p. 32, pl. 3, fig. 10.

—— [*Dalmanites* (*Cryphæus*)] **boothi** var. **calliteles** Hall and Clarke, 1888; Pal. New York, vol. 7, p. 45, pl. 16, figs. 5–22; pl. 16 a, figs. 9–17.

—— [*Dalmanites* (*Cryphæus*)] **comis** Hall, 1888; Pal. New York, vol. 7, p. 41, pl. 16 a, fig. 1. Corniferous.

—— [*Dalmania*] **pleione** Hall, 1861; Des. New Species Fossils, p. 62. Hamilton.

—— [*Dalmania*] **pleione** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 90.

—— [*Dalmanites*] **pleione** Hall, 1876; Illus. Devonian Foss., pl. 16, fig. 17.

—— **pleione** Kayser, 1878; Abhandl. geol. Specialkarte Pr., vol. 2, pt. 4, p. 33.

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Cryphæus [*Dalmanites* (*Cryphæus*)] **pleione** Hall, 1888; Pal. New York, vol. 7, p. 41, pl. 16 a, fig. 2.

Cryptolithus Green, 1832; Mon. Tril. North America, p. 72.
This generic should replace that of *Trinucleus* Murch., 1839.

Cryptonymus Eichwald, 1825; Syn. to *Asaphus*, *Illænus*, and *Niobe*.

Cryptonymus Eichwald, 1840. (See **Encrinurus**.)

Cybele Löven, 1845; Svenska Vetensk. Akad. Förhandl., p. 110.
Type, *Cybele bellatula* Dalman.

—— *punctata* Hall. (See **Encrinurus ornatus**.)

Cyphaspis Burmeister, 1843; Org. Trilobiten, p. 98.
Type, *Cyphaspis ceratopthalma* Burmeister.

—— **christyi** Hall, 1863; Trans. Albany Inst., vol. 4, p. 220. Niagara.

—— **christyi** Hall, 1875; 28th Rept. New York State Mus. Nat. Hist., pl. 32, figs. 5–7.

—— **christyi** Hall, 1879; 28th Rept. New York State Mus. Nat. Hist., p. 188, pl. 32, figs. 5–7.

—— **christyi** White, 1880; 2d Ann. Rept. Dept. Statistics and Geol. Indiana, p. 493, pl. 3, fig. 9.

—— **christyi** Hall, 1882; 11th Ann. Rept. Dept. Geol. Nat. Hist. Indiana, 1881, p. 333, pl. 34, figs. 5–7.

—— **cœlebs** Hall, 1888; Pal. New York, vol. 7, p. 151, pl. 24, fig. 1.
Lower Helderberg.

—— **craspedota** Hall, 1888; Pal. New York, vol. 7, p. 148, pl. 24, figs. 15–20.
Hamilton.

—— **diadema** Hall, 1888; Pal. New York, vol. 7, p. 144, pl. 24, fig. 13.
Upper Helderberg.

—— **girardeauensis** Shumard, 1855; 1st and 2d Rept. Geol. Missouri, p. 197, pl. B, fig. 11 a, b.

—— **girardeauensis** Emmons, 1860; Manual Geology, p. 159, fig. 145 (2).

—— **hybrida** Hall, 1888; Pal. New York, vol. 7, p. 144, pl. 24, fig. 14.
Upper Helderberg.

—— [*Phillipsia*] **lævis** Hall, 1876; Illus. Devonian Foss., pl. 21, fig. 29.

—— **lævis** Hall, 1888; Pal. New York, vol. 7, p. 150, pl. 21, fig. 29. Chemung.

—— [*Phillipsia*] **minuscula** Hall, 1876; Illus. Devonian Foss., pl. 20, fig. 17.
Upper Helderberg.

—— **minuscula** Hall, 1888; Pal. New York, vol. 7, p. 140, pl. 20, fig. 17; pl. 24, figs. 7–12.

—— [*Phillipsia?* (*Brachymetopus?*)] **ornata** Hall, 1876; Illus. Devonian Foss., pl. 21, fig. 1. Hamilton.
Syn., *Phillipsia coronata* Miller, 1877; Catalogue Am. Pal. Foss., p. 221.
Phillipsia coronata? Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 211.

—— **ornata** Hall, 1888; Pal. New York, vol. 7, p. 145, pl. 21, fig. 1; pl. 24, fig. 21.

—— **ornata** var. **baccata** Hall, 1888; Pal. New York, vol. 7, p. 146, pl. 24, figs. 22, 23.

—— **stephanophora** Hall, 1888; Pal. New York, vol. 7, p. 142, pl. 24, figs. 2–6.
Upper Helderberg.

Dalmania Emmrich, 1844; Zur Naturgeschichte Trilobiten, p. 15.
This name having been used in 1830 for a genus of the Diptera, J. Barrande suggested that of *Dalmanites*.

Dalmanites (Emmrich) Barrande, 1872; Syst. Sil. Bohême, Suppl., vol. 1, p. 27.
Type, *Dalmanites caudatus* Bünnich.
Syn., *Pleuracanthus* Milne-Edwards, 1840; Crust., vol. 3, p. 329.
Odontochile Corda, 1847; Prodr., p. 208, pl. 5, fig. 56.
Osteropyge Corda, 1847; Prodr., p. 241, pl. 6, fig. 66.
Metacanthus Corda, 1847; Prodr., p. 242, pl. 6, fig. 67.
Chasmops McCoy, 1849; Annals Nat. Hist., 2d series, vol. 4.

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Syn., *Cryphæus* Green, 1837; Am. Jour. Sci., 1st series, vol. 32, p. 343.
Odontocephalus Conrad, 1840; 3d Rept. Pal. Dept. New York Geol. Survey, p. 204.
Hausmannia Hall, 1888; Pal. New York, vol. 7, p. xxxi.
Coronura Hall, 1888; Pal. New York, vol. 7, p. xxxii.
Corycephalus Hall, 1888; Pal. New York, vol. 7, p. xxxiv.

Dalmanites [*Asaphus?*] **acantholeurus** (Conrad) Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 113.

—— [*Asaphus?*] **acantholeurus** Conrad, 1841; 4th Rept. Pal. Dept. New York Geol. Survey, p. 48. Onondaga.

—— **acantholeurus** Hall, 1876; Illus. Devonian Foss. Crust., pl. 19, fig. 14.

—— [*Dalmanites*] **acantholeurus** Hall, 1876; Illus. Devonian Foss. Crust., pl. 19, fig. 14.

—— **achates** Billings, 1860; Canadian Naturalist, vol. 5, p. 63, fig. 9. Trenton.

—— **achates** Billings, 1863; Geol. Canada, p. 187, fig. 186.

—— **ægeria** Hall, 1861; Des. New Species Fossils, p. 57. Upper Helderberg.

—— **ægeria** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 85.

—— **ægeria** Hall, 1876; Illus. Devonian Foss. Crust., pl. 12, figs. 1, 2, 7.

—— **ægeria** Hall, 1876; Illus. Devonian Foss. Crust., p. 12, figs 3, 6, 8 (not figs. 1, 2, 7).

—— [*Odontocephalus*] **ægeria** Meek and Worthen, 1868; Geol. Illinois, vol. 3, p. 417, pl. 10, figs. 4 a, b, c.

—— [*Odontocephalus*] **ægeria** Hall, 1888; Pal. New York, vol. 7, p. 53, pl. 11 b, figs. 1–11.

—— [*Calymene*] **anchiops** Green, 1832; Monthly Am. Jour. Geol., vol. 1, p. 558. Upper Helderberg.

—— [*Calymene*] **anchiops** Green, 1832; Mon. Tril. N. A., p. 35, cast 7.
Syn., *Asaphus laticostatus* Green, 1832; Monthly Am. Jour. Geol., vol. 1, p. 559.
Asaphus laticostatus Green, 1832; Mon. Tril. N. A., p. 45, cast 13.

—— [*Phacops*] **anchiops** Burmeister, 1843; Org. Trilobiten, p. 90 (Ray Soc. edition).

—— [*Phacops*] **anchiops** Hall, 1851; Rept. Geol. Lake Superior Land Dist. (Foster and Whitney), pt. 2, p. 224, pl. 35, figs. 3 a, 3 b. (See **Dalmanites anchiops** var. **armatus**.)

—— [*Dalmania*] **anchiops** Hall, 1861; Des. New Species Fossils, p. 55.

—— [*Dalmania*] **anchiops** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 83.

—— **anchiops** Hall, 1876; Illus. Devonian Foss. Crust., p. 9, figs. 1, 3–6, 9, 10, 12, 13; pl. 10, figs. 6–14.

—— [*Chasmops*] **anchiops** Hall, 1888; Pal. New York, vol. 7, p. 59, pl. 9, figs. 1–6, 10, 12, 13; pl. 10, figs. 1–14.

—— [*Dalmania*] **anchiops** var. **armatus** Hall, 1861; Des. New Species Foss., p. 56.

—— [*Dalmania*] **anchiops** var. **armatus** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 84.

—— **anchiops** var. **armatus** Hall, 1876; Illus. Devonian Foss. Crust., pl. 9, figs. 2, 7, 8.

—— [*Chasmops*] **anchiops** var. **armatus** Hall, 1888; Pal. New York, vol. 7, p. 62, pl. 9, figs. 7–9; pl. 10, fig. 14.

—— [*Chasmops*] **anchiops** var. **sobrinus** Hall, 1888; Pal. New York, vol. 17, p. 62, pl. 9, fig. 11.

—— [*Odontocephalus*] **arenarius** Meek and Worthen, 1868; Geol. Survey Illinois, vol. 3, p. 417, pl. 9, fig. 10. (See **Dalmanites selenurus**.)

—— [*Asaphus*] **aspectans** Conrad, 1841; 5th Ann. Rept. Pal. Dept. New York Geol. Survey, p. 48, fig. 9. Upper Helderberg.
Syn., *Asaphus? denticulatus* Conrad; *idem.*, p. 48.

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Dalmanites [*Dalmania*] **aspectans** Hall, 1861; Des. New Species Foss., p. 60 (in error *D. adspectans*).

—— [*Dalmania*] **aspectans** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 88 (in error *D. adspectans*).

Syn., *Dalmania helena* Hall, 1861; Des. New Species Foss., p. 61.

Dalmania helena Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 89.

Dalmanites ohioensis Meek, 1871; Proc. Acad. Nat. Sci. Phila., p. 91.

Dalmanites ohioensis Meek, 1873; Pal. Ohio, vol. 1, p. 234, pl. 23, fig. 1.

Dalmanites denticulatus Hall, 1876; Illus. Devonian Foss. Crust., pl. 10, fig. 1.

—— **aspectans** Hall, 1876; Illus. Devonian Foss. Crust., pl. 13, figs. 6–8.

Syn., *helena* Hall, 1876; Illus. Devonian Foss. Crust., pl. 13, figs. 13, 14.

—— [*Coronura*] **aspectans** Hall, 1888; Pal. New York, vol. 7, p. 33, pl. 12, figs. 1–11, 13.

—— [*Cryphæus*] *barrisi* Hall. (See **Cryphæus barrisi** Hall.)

—— **bebryx** Billings, 1860; Canadian Naturalist, vol. 5, p. 62, fig. 8. Trenton.

—— **bebryx** Billings, 1863; Geol. Canada, p. 187, fig. 185.

—— [*Dalmania*] **bifida** Hall, 1861; Des. New Species Foss., p. 63. Upper Helderberg.

—— [*Dalmania*] **bifida** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 91.

—— [*Odontocephalus*] **bifida** Hall and Clarke, 1888; Pal. New York, vol. 7, p. 53, pl. 11 b, figs. 22–25.

Compare *Dalmanites ægeria* Hall.

—— [*Dalmania*] *boothi*. (See **Cryphæus boothi** Green.)

—— **bicornis** Hall, 1875; 28th Rept. New York State Mus. Nat. Hist. Expl., pl. 33, fig. 18. Niagara.

—— **bicornis** Hall, 1879; 28th Rept. New York State Mus. Nat. Hist., p. 196, pl. 33, fig. 18.

—— **bicornis** Hall, 1882; 11th Ann. Rept. Geol. Nat. Hist. Indiana, 1881, p. 342, pl. 35, fig. 18.

—— **breviceps** Hall, 1866; 24th Rept. New York State Mus. Nat. Hist., p. 223, pl. 8, figs. 15, 16. Hudson.

—— **breviceps** Miller, 1874; Cincinnati Quart. Jour. Sci., vol. 1, p. 143.

—— **breviceps** Hall and Whitfield, 1875; Pal. Ohio, vol. 2, p. 108, pl. 4, figs. 15, 16.

—— [*Phacops*] **callicephalus** Hall, 1847; Pal. New York, vol. 1, p. 247, pl. 65, figs. 3 a–3 i. Trenton.

—— [*Phacops*] **callicephalus** Hall, 1851; Rept. Geol. Lake Superior Land Dist. (Foster and Whitney), vol. 2, p. 212, pl. 3, figs. 3 a, 3 b.

—— [*Phacops*] **callicephalus** Emmons, 1855; Am. Geology, vol. 1, pt. 2, p. 214, pl. 15, figs. 7, 7 a.

—— [*Dalmania*] *calliteles*. (See **Cryphæus calliteles**).

—— [*Dalmania*] **calypso** Hall, 1861; Des. New Species Foss., p. 61. Upper Helderberg.

—— [*Dalmania*] **calypso** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 89.

—— **calypso** Hall, 1876; Illus. Devonian Foss. Crust., pl. 13, figs. 1, 2.

—— [*Chasmops*] **calypso** Hall, 1888; Pal. New York, vol. 7, p. 4, pl. 16 a, fig. 1.

—— ? **cayahogoe** Claypole, 1884; Geol. Mag., vol. 1, p. 305, figure. Carboniferous.

—— ? **cayahogoe** Woodward, 1884; Mon. Brit. Carboniferous Tril., p. 79, figure.

—— **carleyi** Meek, 1872; Am. Jour. Sci., 3d series, vol. 3, p. 424. Hudson.

—— **carleyi** Meek, 1873; Pal. Ohio, vol. 1, p. 170, pl. 14, figs. 2 a–2 d.

—— **carleyi** Miller, 1874; Cincinnati Quart. Jour. Sci., vol. 1, p. 142.

—— [*Dalmania*] *caudata* (Brong.) Roemer. (See **Dalmanites limulurus** Green.)

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Dalmanites [*Cryphæus*] *comis.* (See **Cryphæus comis** Hall.)
—— **concinnus** Hall, 1876; Illus. Devonian Foss. Crust., pl. 10, figs. 3–5. Schoharie.
—— [*Hausmannia*] **concinnus** Hall, 1888; Pal. New York, vol. 7, p. 30, pl. 11 a, figs. 9–11.
—— [*Hausmannia*] **concinnus** var. **serrula** Hall and Clarke, 1888; Pal. New York, vol. 7, p. 30, pl. 11 a, fig. 12.
—— [*Dalmania*] **coronatus** Hall, 1861; Des. New Species Foss., p. 58.
Upper Helderberg.
—— [*Dalmania*] **coronatus** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 86.
—— **coronatus** Hall, 1876; Illus. Devonian Foss. Crust., pl. 12, figs. 15–17; pl. 13, fig. 5.
—— [*Odontocephalus?*] **coronatus** Hall, 1888; Pal. New York, vol. 7, p. 54, pl. 11 b, figs. 12–14.
—— **danæ** Meek and Worthen, 1865; Proc. Acad. Nat. Sci. Phila., p. 264. Niagara.
—— **danæ** Meek and Worthen, 1868; Pal. Illinois, vol. 3, p. 363, pl. 6, figs. 1 a–1 f.
—— **dentata** Barrett, 1876; Am. Jour. Sci., 3d series, vol. 11, p. 200, plate.
Lower Helderberg.
—— **dentata** Barrett, 1876; Am. Jour. Sci., 3d series, vol. 12, p. 70.
—— [*Corycephalus*] **dentatus** Hall and Clarke, 1888; Pal. New York, vol. 7, p. 58, pl. 11 a, figs. 4–6.
—— [*Asaphus?*] **denticulatus** Conrad, 1841; 5th Rept. Pal. Dept. New York Geol. Survey, p. 48.
Lower Helderberg.
—— **denticulatus** Hall, 1876; Illus. Devonian Foss. Crust., pl. 10, fig. 1.
—— [*Phæton*] **denticulatus** Meek, 1877; U. S. Geol. Expl. 40th Par., vol. 4, p. 49, pl. 1, figs. 10 a, b.
—— **emarginatus** Hall, 1876; Illus. Devonian Foss. Crust., pl. 10, fig. 2.
Upper Helderberg.
—— [*Coronura*] **emarginatus** Hall, 1888; Pal. New York, vol. 7, p. 40, pl. 11 a, figs. 7, 8.
—— **epiorates** Billings, 1863; Proc. Portland Soc. Nat. Hist., vol. 1, p. 119, pl. 1, fig. 21.
—— [*Dalmania*] **erina** Hall, 1861; Des. New Species Foss., p. 62.
Upper Helderberg.
—— [*Dalmania*] **erina** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 90.
—— **erina** Hall, 1876; Illus. Devonian Foss. Crust., pl. 13, figs. 3, 4.
—— [*Chasmops*] **erina** Hall, 1888; Pal. New York, vol. 7, p. 67, pl. 11, figs. 16–18.
Upper Silurian.
—— [*Dalmania*] *helena.* (See **Dalmanites aspectans.**)
—— **intermedius** Walcott, 1877; Advance sheets 31st Rept. New York State Cab. Nat. Hist., p. 17. Trenton.
—— **intermedius** Walcott, 1879; 31st Rept. New York State Cab. Nat. Hist., p. 69.
—— [*Phacops?*] **laticauda** Hall, 1847; Pal. New York, vol. 1, p. 248, pl. 64, fig. 3.
—— [*Asaphus*] **limulurus** Green, 1832; Monthly Am. Jour. Geol., vol. 1, p. 559.
Niagara.
—— [*Asaphus*] **limulurus** Green, 1832; Mon. Tril. N. A., p. 48, cast 16.
—— [*Phacops*] **limulurus** Hall, 1852; Pal. New York, vol. 2, p. 303, pl. 67, figs. 1–8.
Syn. [*Dalmania*] *caudata* (Brong.) Roemer, 1860; Die sil. Fauna W. Tenn., p. 82, pl. 5, fig. 21.
—— [*Dalmania*] **logani** Hall, 1860; Canadian Naturalist, vol. 5, p. 156, fig. 18.
Silurian.
—— [*Dalmania*] **macrops** Hall, 1861; Des. New Species Foss., p. 59.
Upper Helderberg.
—— [*Dalmania*] **macrops** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 87.

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Dalmanites macrops, 1876; Illus. Devonian Foss. Crust., pl. 13, figs. 9, 10.
—— [*Chasmops*] **macrops** Hall, 1888; Pal. New York, vol. 7, p. 68, pl. 11 a, figs. 14, 15.
—— **macroura** ? (Sjogr.) Billings, 1866; Catalogue Sil. Foss. Anticosti, p. 61.
—— [*Dalmania*] **meta** Hall, 1862; Geol. Wisconsin, vol. 1, p. 433.
—— **meeki** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 207, pl. 17, figs. 5–5 a, b (not fig. 5 c).
—— (undetermined sp.) Meek, 1877; U. S. Geol. Expl. 40th Par., vol. 4, p. 48, pl. 1, figs. 11, 11 a.
—— [*Hausmannia*] **meeki** Hall, 1888; Pal. New York, vol. 7, p. 11 a, figs. 28–30.
—— [*Asaphus*] **micrurus** Green, 1832; Monthly Am. Jour. Geology, p. 559, pl. 14, fig. 3. Lower Helderberg.
—— [*Asaphus*] **micrurus** Green, 1832; Mon. Tril. N. A., p. 56, cast 19, pl., fig. 3.
—— [*Dalmania*] **micrurus** Hall, 1859; Pal. New York, vol. 3, p. 359, pl. 75, figs. 13–18.
—— [*Asaphus*] **myrmecophorus** Green, 1835; Am. Jour. Sci., 1st series, vol. 23, p. 397. Upper Helderberg.
—— [*Asaphus*] **myrmecophorus** Green, 1835; Suppl. Mon. Tril. N. A., p. 16, cast 40.
—— [*Dalmania*] **myrmecophorus** Hall, 1861; Des. New Species Foss., p. 60.
—— [*Dalmania*] **myrmecophorus** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 88.
—— **myrmecophorus** Hall, 1876; Illus. Devonian Foss. Crust., pl. 13, figs. 15, 16.
—— [*Coronura*] **myrmecophorus** Hall, 1888; Pal. New York, vol. 7, p. 37, pl. 11 a, fig. 13; pl. 13, fig. 12; pl. 14, figs. 1–6; pl. 15, figs. 1–4.
—— [*Asaphus*] **nasutus** Conrad, 1841; 5th Rept. Pal. Dept. New York Geol. Survey, p. 48. Lower Helderberg.
—— [*Dalmania*] **nasutus** Hall, 1859; Pal. New York, vol. 3, p. 362, pl. 75, fig. 2; pl. 76, figs. 1–9.
—— [*Dalmanites*] *ohioensis*. (See **Dalmanites aspectans**.)
—— [*Hausmannia*] **phacoptyx** Hall, 1888; Pal. New York, vol. 7, p. 31, pl. 11 a, figs. 23–29. Upper Helderberg.
—— [*Dalmania*] *pleione*. (See **Cryphæus pleione**.)
—— [*Asaphus*] **pleuropteryx** Green, 1832; Monthly Jour. Geol., vol. 1, p. 559. Lower Helderberg.
—— [*Asaphus*] **pleuropteryx** Green, 1832; Mon. Tril. N. A., p. 55, cast 18.
—— [*Dalmania*] **pleuropteryx** Hall, 1859; Pal. New York, vol. 3, p. 356, pl. 74, figs. 5 (?) 9 (?) (not figs. 1–4, 6–8, 10–12), pl. 75, fig. 1.
—— [*Hausmannia*] **pleuropteryx** Hall, 1888; Pal. New York, vol. 7, p. 28, pl. 9, figs. 1–3.
—— [*Corycephalus*] **pygmæus** Hall, 1888; Pal. New York, vol. 7, p. 56, pl. 11, figs. 5–8. Upper Helderberg.
—— **regalis** Hall, 1876; Illus. Devonian Foss. Crust., pl. 11, figs. 1–4. Upper Helderberg.
—— [*Corycephalus*] **regalis** Hall, 1888; Pal New York, vol. 7, p. 55, pl. 11, figs. 1–4.
—— [*Asaphus*] **selenurus** Eaton, 1832; Geological Text Book, p. 31, pl. 1, fig. 1. Upper Helderberg.
—— [*Asaphus*] **selenurus** Green, 1832; Mon. Tril. N. A., p. 46, casts 14 and 15.
Syn., *Calymene? odontocephala* Green, 1835; Suppl. Mon. Tril. N. A., p. 9, cast 36.
Calymene? odontocephala Green, 1835; Am. Jour. Sci., 1st series, vol. 25, p. 334.
—— [*Odontocephalus*] **selenurus** Conrad, 1840; 3d Rept. Pal. Dept. New York Geol. Survey, p. 204.
—— [*Odontocephalus*] **selenurus** Vanuxem, 1842; Geol. New York, 3d Geol. Dist., pp. 139, 140, fig. 1.
—— [*Odontocephalus*] **selenurus** Hall, 1843; Geol. New York, 4th Geol. Dist., p. 175, fig. 1.

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Dalmanites [*Dalmania*] **selenurus** Hall, 1859; 12th Rept. New York State Cab. Nat. Hist., p. 88.

—— [*Dalmania*] **selenurus** Hall, 1861; Des. New Species Foss., p. 56.

—— [*Dalmania*] **selenurus** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 84.

Syn., *Odontocephalus?* (*Dalmanites–Odontocephalus*) *arenarius* Meek and Worthen, 1868; Geol. Survey Illinois, vol. 3, p. 416, pl. 9, fig. 10.

—— **selenurus** Hall, 1876; Illus. Devonian Foss. Crust., pl. 12, figs. 12–14.

—— [*Odontocephalus*] **selenurus** Hall, 1888; Pal. New York, vol. 7, p. 49, pl. 11 b, figs. 15–21; pl. 12, figs. 1–13.

—— [*Dalmania*] **tridens** Hall, 1859; Pal. New York, vol. 3, p. 361, pl. 75, figs. 3–6. Lower Helderberg.

—— [*Dalmania*] **tridentifera** Shumard, 1855; 1st and 2d Geol. Repts. Missouri, p. 199, pl. B, figs. 8 a–c. Lower Helderberg.

—— **tridentifera** Meek and Worthen, 1868; Pal. Illinois, vol. 3, p. 391, pl. 7, fig. 16.

—— *troosti* Safford, 1869; Geol. Tennessee, p. 290. (See **Chasmops troosti** Safford.) Nashville.

—— [*Dalmania*] **verrucosus** Hall, 1863; Trans. Albany Inst., vol. 4, p. 218. (Abstract published May, 1863, p. 24.) Niagara.

—— **verrucosus** Hall, 1875; 28th Rept. New York State Mus. Nat. Hist., pl. 23, figs. 5–17, 13–15. Museum ed., 1879, p. 195, pl. 23, fig. 5–17; pl. 34, figs. 13–15.

—— **verrucosus** Hall, 1882; 11th Ann. Rept. Dept. Geol. Nat. Hist. Indiana, p. 341, pl. 35, figs. 5–17; pl. 36, figs. 13–15.

—— **vigilans** Hall, 1861; Rept. Progress Wisconsin Geol. Survey, p. 51. Niagara.

—— [*Dalmania*] **vigilans** Hall, 1867; 20th Rept. New York State Cab. Nat. Hist., p. 335, pl. 21, figs. 16–18.

—— [*Dalmania*] **vigilans** Hall, 1870; 20th Rept. New York State Cab. Nat. Hist. (2d ed.), p. 426, pl. 21, figs. 16–18.

—— **vigilans** Hall, 1875; 28th Rept. New York State Mus. Nat. Hist. Expl., pl. 33, figs. 1–4.

—— **vigilans** Hall, 1879; 28th Rept. New York State Mus. Nat. Hist. (Mus. ed.), p. 193, pl. 33, figs. 1–4.

—— **vigilans** Hall, 1882; 11th Ann. Rept. Geol. Nat. Hist. Indiana, 1881, p. 339, pl. 35, figs. 1–4; pl. 33, fig. 9.

—— **werthneri** Foerste, 1885; Bull. Denison Univ., vol. 1, p. 116. Clinton.

—— **werthneri** Foerste, 1887; Bull. Denison Univ., vol. 2, p. 109, pl. 8, figs. 22–25.

Dicellocephalus. (See **Dikelocephalus.**)

Dikelocephalus Owen, 1852; Rept. Geol. Survey Wisconsin, Iowa, and Minnesota, p. 573.

Type, *Dikelocephalus minnesotensis* Owen.

Syn., *Centropleura* Angelin, 1854; Pal. Scand., p. 87, pl. 41, figs. 9–11.

This generic term has sometimes been spelled *Dicellocephalus.*

—— **affinis** Billings, 1865; Pal. Foss., vol. 1, p. 197, fig. 183 a, b. Quebec.

—— ? **angustifrons** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8. p. 42, pl. 10, figs. 1, 1 a, b. Cambrian.

—— **belli** Billings, 1860; Canadian Naturalist, vol. 5, p. 311, fig. 7. Quebec.

—— **belli** Billings, 1865; Pal. Foss., vol. 1, p. 403, fig. 378.

—— **barabuensis** Whitfield, 1878; Ann. Rept. Geol. Survey Wisconsin, 1877, p. 63. Lower Magnesian.

—— **barabuensis** Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 201, pl. 4, figs. 6–9.

Compare *Bathyurus capax* Billings.

—— **bilobatus** Hall and Whitfield, 1877; U. S. Geol. Expl. 40th Par., p. 226, pl. 2, fig. 36. Potsdam.

—— **bilobatus** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 40.

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Dikelocephalus crassimarginatus Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 344, pl. 27, fig. 14. Potsdam.

Syn., *pepinensis* (Hall), 16th Rept. New York State Cab. Nat. Hist. Expl., pl. 11. fig. 2.

—— ? **corax** Billings, 1865; Pal. Foss., vol. 1, p. 344, figs. 322 a, b. Quebec.

Referred to *Olenoides ? corax* Walcott, 1884; Bull. U. S. Geol. Survey, No. 30, p. 184.

—— **cristatus** Billings, 1860; Canadian Naturalist, vol. 5, p. 312, fig. 10. Quebec.

—— **cristatus** Billings, 1865; Pal. Foss., vol. 1, p. 404, fig. 384.

This species might be referred to the genus *Dorypyge*.

—— **devinei** Billings, 1865; Pal. Foss., vol. 1, p. 195, figs. 180, 181. Quebec.

—— **eatoni** Whitfield, 1878; Ann. Rept. Geol. Survey Wisconsin, 1877, p. 65. Lower Magnesian.

—— **eatoni** Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 202, pl. 4, figs. 11–17; pl. 10, figs. 4, 5.

—— ? **expansus** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 89, pl. 9, fig. 19. Cambrian.

—— **finalis** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 89, pl. 12, figs. 12 a, b. Pogonip.

—— **flabellifer** Hall and Whitfield, 1877; U. S. Geol. Expl. 40th Par., vol. 4, p. 227, pl. 2, figs. 29, 30. Potsdam.

—— *flagricaudus* White. (See **Olenoides ? flagricauda.**)

—— ? *gothicus* Hall and Whitfield. (See **Dorypyge gothicus.**)

—— **hisingeri** Billings, 1865; Pal. Foss., vol. 1, p. 196, fig. 182. Quebec.

—— **inexpectans** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 90, pl. 1, fig. 10. Pogonip.

—— ? *iowensis* Owen. (See **Crepicephalus iowensis** (Owen) Walcott.)

—— **iole** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 43, pl. 10, fig. 19. Cambrian.

—— **latifrons** Shumard, 1863; Trans. Acad. Sci. St. Louis, vol. 2, p. 101. Potsdam.

—— **lodensis** Whitfield, 1880; Ann. Rept. Geol. Survey Wisconsin, 1879, p. 51. Potsdam.

—— **lodensis** Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 188, pl. 10, fig. 14; p. 341, pl. 27, figs. 12, 13.

—— **magnificus** Billings, 1860; Canadian Naturalist, vol. 5, p. 307, fig. 5 (*Remopleurides magnificus* Billings, 1865; Pal. Foss., vol. 1, p. 294). Quebec.

—— **magnificus** Billings, 1865; Pal. Foss., vol. 1, p. 399, fig. 376.

—— ? **marcoui** Whitfield, 1884; Bull. Am. Mus. Nat. Hist. New York, vol. 1, p. 150, pl. 14, fig. 7. Potsdam.

Referred to *Olenoides marcoui* Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 186, pl. 26, figs. 5, 5 a, b.

—— **marica** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 44, pl. 10, fig. 13. Cambrian.

—— **megalop** Billings, 1860; Canadian Naturalist, vol. 5, p. 311, fig. 9. Quebec.

—— **megalop** Billings, 1865; Pal. Foss., vol. 1, p. 403, fig. 380.

—— *miniscaensis*. (See **Ptychaspis miniscaensis.**)

—— **minnesotensis** Owen. Cambrian.

A very large sp. *Asaphus* Owen, 1848; Rept. Geol. Reconnoissance Chippewa Land Dis., p. 15, pl. 7, figs. 2, 3.

—— **minnesotensis** Owen, 1852; Rept. Geol. Survey Wisconsin, Iowa, and Minnesota, p. 574, pl. 1, figs. 2, 10; pl. 10, figs. 3, 6.

—— **minnesotensis** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 138, pl. 9, figs. 5–10; pl. 10, figs. 10–12; pl. 11, figs. 1–4, 6.

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Dikelocephalus minnesotensis var. **limbatus** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 141, pl. 9, fig. 12.
—— **minnesotensis** var. Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 141, pl. 9, fig. 11; pl. 10, fig. 9.
—— **minnesotensis** Winchell, 1864; Am. Jour. Sci., 2d series, vol. 37, p. 229.
—— **minnesotensis** Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 187, pl. 3, fig. 1.
—— **misa** Hall, 1863; 16th Rept. State Cab. Nat. Hist., p. 144, pl. 8, fig. 15; pl. 10, figs. 4–8. Potsdam.
—— **missisquoi** Billings, 1865; Pal. Foss., vol. 1, p. 199. Quebec.
—— **multicinctus** Hall and Whitfield, 1877; U. S. Geol. Expl. 40th Par., vol. 4, p. 226, pl. 2, fig. 37. Potsdam.
—— **nasutus** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 40, pl. 10, fig. 15. Cambrian.
—— **osceola** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 146, pl. 7, fig. 49; pl. 10, fig. 18. Potsdam.
—— **osceola** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 40, pl. 9, fig. 25.
—— **oweni** Billings, 1860; Canadian Naturalist, vol. 5, p. 310, fig. 8. Quebec.
—— **oweni** Billings, 1865; Pal. Foss., vol. 1, p. 402, fig. 379.
—— **pauper** Billings, 1865; Pal. Foss., vol. 1, p. 200. Quebec.
—— **pepinensis** Owen, 1852; Rept. Geol. Survey Wisconsin, Iowa, and Minnesota, p. 574, pl. 1, figs. 9, 9 a; pl. 1 a, fig. 7. Potsdam.
—— **pepinensis** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 142, pl. 9, figs. 1–4; pl. 10, figs. 13–17. (Expl., pl. 11, fig. 2. See **Dicellocephalus crassimarginatus.**)
—— **pepinensis** Winchell, 1864; Am. Jour. Sci., 2d series, vol. 37, p. 229.
—— **planifrons** Billings, 1860; Canadian Naturalist, vol. 5, p. 309, fig. 6. Quebec.
—— **planifrons** Billings, 1865; Pal. Foss., vol. 1, p. 401, fig. 377.
—— *quadriceps.* (See **Dorypyge quadriceps.**)
—— **richmondensis** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 41, pl. 10, fig. 7. Cambrian.
—— **roemeri** Shumard, 1861; Am. Jour. Sci., 2d series, vol. 32, p. 220. Potsdam.
—— **selectus** Billings, 1865; Pal. Foss., vol. 1, p. 199. Quebec.
—— **selectus** Billings, 1865; Pal. Foss., vol. 1, p. 198. (See **Ptychaspis selectus.**)
—— **spiniger** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 143, pl. 10, figs. 1, 2, 3 (?). Potsdam.
—— *wahsatchensis.* (See **Olenoides wahsatchensis.**)

Dionide Barrande, 1847; Neues Jahrbuch für Mineral., vol. 4, p. 391.
Type, *Dionide formosa* Barrande.
Syn., *Dione* Barrande; Notice Prélim. Sil. Syst. Bohême, p. 33.
Polytomurus Corda, 1847; Prodr., p. 153.
—— ? **perplexa** Billings, 1866; Catalogue Sil. Foss. Anticosti, p. 67.

Dipleura Green, 1832; Mon. Tril. North America, p. 79. (See **Homalonotus dekayi.**)

Discranurus Conrad, 1841; 5th Rept. Pal. Dept. New York Geol. Survey, p. 48. (See **Acidaspis hamata.**)

Dolichometopus Angelin, 1854; Palæont. Scand., p. 72.
Type, *Dolichometopus svecicus* Ang.
—— ? **convexus** Billings, 1865; Pal. Foss., vol. 1, p. 269, fig. 253. Quebec.
—— ? **gibberrulus** Billings, 1865; Pal. Foss., vol. 1, p. 269, fig. 254. Quebec.
—— ? **rarus** Billings, 1865; Pal. Foss., vol. 1, p. 352, fig. 308. Quebec.

Dorypyge Dames, 1884; China (Richthofen), vol. 4, p. 23.
Type, *Dorypyge richthofeni* Dames.
—— [*Dikelocephalus*] **cristatus** Billings, 1865; Pal. Foss., vol. 1, p. 404, fig. 384. Cambrian.

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Dorypyge [*Dikelocephalus?*] **gothicus** Hall and Whitfield, 1877; U. S. Geol. Expl. 40th Par., vol. 4, p. 242, pl. 1, fig. 36. Potsdam.
—— **gothicus** Dames, 1884; China (Richthofen), vol. 4, p. 23.
—— [*Dicellocephalus?*] **gothicus** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 45, pl. 9, fig. 24. Referred to
—— [*Olenoides*] **gothicus** Walcott, 1886; Bull. U. S. Geol. Survey, vol. 30, p. 187, pl. 29, figs. 1, 1 a–c.
—— [*Dikelocephalus*] **quadriceps** Hall and Whitfield, 1877; U. S. Geol. Expl. 40th Par., vol. 4, p. 240, pl. 1, figs. 37–40. Cambrian.
—— [*Dicellocephalus*] **quadriceps** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol, 8, p. 45, pl. 9, fig. 24.
—— **quadriceps** Dames, 1884; China (Richthofen), vol. 4, p. 23. Referred to
—— [*Olenoides*] **quadriceps** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 187, pl. 29, figs. 1, 1 a–c.
Dysplanus Burmeister, 1843; Organization of Trilobites (Ray Soc. ed., p. 205).
Type, *Dysplanus centrotus* Dalman.
Ellipsocephalus Zenker, 1833; Beiträge Naturgeschichte der Urwelt, p. 51.
Type, *Ellipsocephalus hoffi* Bronn.
—— **curtus** Whitfield, 1878; Ann. Rept. Geol. Wisconsin, 1877, p. 58. Potsdam.
—— **curtus** Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 191, pl. 1, fig. 18.
Eliptocephalus Emmons, 1844; Taconic Syst., p. 21, figs. 1–3.
—— *asaphoides*. (See **Olenellus asaphoides** Emmons.)
Embolimus Rominger, 1887; Proc. Acad. Nat. Sci. Phila., p. 16. (See **Zacanthoides** Walcott.)
—— *rotundata*. (See **Bathyùriscus howelli.**)
—— *spinosa*. (See **Olenoides spinosus.**)
Encrinurus Emmrich, 1844; Zur Naturg. Trilobiten, p. 16.
Type, *Encrinurus punctatus* Brünnich.
—— **americanus** Vogdes, 1886; Des. New Crust. Clinton Group Georgia, p. 1. Clinton.
—— **americanus** Foerste, 1887; Bull. Denison Univ., vol. 2, p. 102.
—— **deltoideus** Shumard, 1855; Geol. Missouri, p. 198, pl. B, fig. 10. Upper Silurian.
—— [*Cryptonymus*] **deltoideus** Vogdes, 1878; Mon. Genera Zethus, etc., p. 21.
—— **deltoideus** Foerste, 1887; Bull. Denison Univ., vol. 2, p. 102.
—— **egani** Miller, 1879; Jour. Cincinnati Soc. Nat. Hist., vol. 2, p. 254, pl. 15, figs. 1, 1 a, b. Niagara.
—— **elegantulus** Billings, 1866; Catalogue Sil. Foss. Anticosti, p. 62.
—— **elegantulus** Foerste, 1887; Bull. Denison Univ., vol. 2, p. 102.
—— *excedrensis* Safford. (See **Encrinurus varicostatus** Walcott.)
Syn., *excedrensis* Safford, 1869; Geol. Tennessee, p. 290.
—— **mirus** Billings, 1865; Pal. Foss., vol. 1, p. 292, fig. 282. Quebec.
—— [*Cryptonymus*] **mirus** Vogdes, 1878; Mon. Genera Zethus, etc., p. 34.
—— [*Amphion*] **multisegmentatus** Portlock, 1843; Geol. Londonderry, etc., p. 291, pl. 3, fig. 6.
—— **multisegmentatus** Salter; Mem. Geol. Survey United Kingdom, decade 7, pl. 4.
—— **multisegmentatus** Billings, 1866; Catalogue Sil. Foss. Anticosti, p. 61.
—— [*Cryptonymus*] **multisegmentatus** Vogdes, 1878; Mon. Genera Zethus, etc., p. 29.
—— **nereus** Hall, 1867; 20th Rept. New York State Cab. Nat. Hist., p. 375, pl. 21, fig. 15. Niagara.
—— **nereus** Hall, 1870; 20th Rept. New York State Cab. Nat. Hist., p. 425, pl. 21, fig. 15.
—— [*Cryptonymus*] **nereus** Vogdes, 1878; Mon. Genera Zethus, etc., p. 24, pl. 3, fig. 17.
—— **ornatus** Hall and Whitfield, 1875; Pal. Ohio, vol. 2, p. 154, pl. 7, fig. 16. Niagara.
Syn., *Cybele punctata* Hall, 1852; Pal. New York, vol. 2, p. 297, pl. A 66, figs, 1 a–k.

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Encrinurus [*Cryptonymus*] **ornatus** Vogdes, 1878; Mon. Genera Zethus, etc., p. 23.
—— **ornatus** Foerste, 1887; Bull. Denison Univ., vol. 2, p. 102.
—— **punctatus** (Brünnich) Billings, 1866; Catalogue Sil. Foss. Anticosti, p. 61.
—— **thresheri** Foerste, 1887; Bull. Denison Univ., vol. 2, p. 101, pl. 8, fig. 26. Clinton.
—— **trentonensis** Walcott, 1877; Advance sheets 31st Rept. New York State Mus. Nat. Hist., p. 15. Trenton.
—— **trentonensis** Walcott, 1879; 31st Rept. New York State Mus. Nat. Hist., p. 68.
—— [*Cryptonymus*] **trentonensis** Vogdes, 1878; Mon. Genera Zethus, etc., p. 28.
—— **varicostatus** Walcott, 1877; Advance sheets 31st Rept. New York State Mus. Nat. Hist., p. 16. Trenton.
—— **varicostatus** Walcott, 1879; 31st Rept. New York State Cab. Nat. Hist., p. 69.
—— [*Cryptonymus*] **varicostatus** Vogdes, 1878; Mon. Genera Zethus, etc., p. 27.
—— **varicostatus** Safford and Vogdes, 1889; Proc. Acad. Nat. Sci. Phila., p. 167, figure.
—— [*Ceraurus*] **vigilans** Hall, 1847; Pal. New York, vol. 1, p. 245, pl. 65, figs. 2 a–2 h. Trenton.
—— [*Ceraurus*] **vigilans** Emmons, 1855; Am. Geology, vol. 1, pt. 2, p. 217, pl. 15, figs. 2 a–2 c.
—— [*Cryptonymus*] **vigilans** Vogdes, 1878; Mon. Genera Zethus, etc., p. 29, pl. 2, figs. 2 a–2 h.
Endymion Billings, 1862; Pal. Foss., vol. 1, p. 94. Changed by author to **Endymionia.**
Endymionia Billings, 1865; Pal. Foss., vol. 1, p. 281.
—— **meeki** Billings, 1862; Pal. Foss., vol. 1, pp. 94 and 281, fig. 84. Quebec.
Griffithides Portlock, 1843; Geol. Rept. Londonderry, etc., p. 310.
Type, *Griffithides longiceps* Portlock.
—— [*Phillipsia* (*Griffithides*)] **bufo** Meek and Worthen, 1870; Proc. Acad. Nat. Sci. Phila., p. 52. Keokuk.
—— [*Phillipsia* (*Griffithides*)] **bufo** Meek and Worthen, 1873; Geol. Survey Illinois, vol. 5, p. 528, pl. 19, fig. 5.
—— **bufo** Vogdes, 1887; Annals New York Acad. Sci., vol. 4, p. 95, pl. 3, figs. 4, 5, 10.
—— [*Proetus*] **granulatus** Wetherby, 1881; Jour. Cincinnati Soc. Nat. Hist., vol. 4, p. 31, pl. 2, figs. 8, 8 a, 9, 9 a. Chester.
—— **granulatus** Vogdes, 1887; Annals New York Acad. Sci., vol. 4, p. 101.
—— [*Phillipsia* (*Griffithides?*)] *lodiensis* Meek. (See **Brachymetopsis lodiensis.**)
—— [*Phillipsia* (*Griffithides*)] **portlocki** Meek and Worthen, 1865; Proc. Acad. Nat. Sci. Phila., p. 268. Keokuk.
—— [*Phillipsia* (*Griffithides*)] **portlocki** Meek and Worthen, 1873; Geol. Survey Illinois, vol. 5, p. 525, pl. 19, fig. 6.
—— **portlocki** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 266, pl. 24, figs. 4, 4 a, b.
—— **portlocki** Vogdes, 1887; Annals New York Acad. Sci., vol. 4, p. 93, pl. 3, fig. 9.
—— [*Phillipsia* (*Griffithides?*)] **sangamonensis** Meek and Worthen, 1865; Proc. Acad. Nat. Sci. Phila., p. 270. Coal Measures.
—— [*Phillipsia* (*Griffithides?*)] **sangamonensis** Meek and Worthen, 1873; Geol. Survey Illinois, vol. 5, p. 615, pl. 32, fig. 4.
—— [*Phillipsia* (*Griffithides?*)] **sangamonensis** White, 1883; 13th Rept. Dept. Geol. Nat. Hist. Indiana, p. 174, pl. 39, figs. 4, 5.
—— [*Phillipsia*] **sangamonensis** Herrick, 1887; Bull. Denison Univ., vol. 2, p. 61, pl. 5, fig. 13.
—— [*Griffithides*] **sangamonensis** Vogdes, 1887; Annals New York Acad. Sci., vol. 4, p. 99, pl. 3, figs. 7, 8.
—— [*Phillipsia* (*Griffithides*)] **scitula** Meek and Worthen, 1865; Proc. Acad. Nat. Sci. Phila., p. 270. Coal Measures.

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Griffithides [*Phillipsia* (*Griffithides*)] **scitula** Meek and Worthen, 1873; Geol. Survey Illinois, vol. 5, p. 612, pl. 32, fig. 3.
—— [*Phillipsia* (*Griffithides*)] **scitula** White, 1883; 13th Ann. Rept. Dept. Geol. Nat. Hist. Indiana, 1882, p. 173, pl. 39, figs. 6–9.
—— [*Phillipsia*] **scitula** Meek, 1872; U. S. Geol. Survey Territories, Final Rept. Nebraska, p. 238, pl. 6, fig. 9.
—— [*Phillipsia*] **scitula** Herrick, 1887; Bull. Denison Univ., vol. 2, p. 62.
—— **scitula** Vogdes, 1887; Annals New York Acad. Sci., vol. 4, p. 97, pl. 2, figs. 11–13.
—— ? **sedaliensis** Vogdes, 1888; Trans. New York Acad. Sci., vol. 7, p. 249. Waverly.
—— [*Phœthonides?*] **sedaliensis** Herrick, 1889; Bull. Denison Univ., vol. 3, p. 57.
Harpes Goldfuss, 1839; Nova Acta Acad. Leop. Carol., vol. 19, p. 358.
Type, *Harpes ungula* Sternb.
—— **antiquatus** Billings, 1859; Canadian Naturalist, vol. 4, p. 469, fig. 38. Chazy.
—— **antiquatus** Billings, 1863; Geol. Canada, p. 133, fig. 67.
—— **consuetus** Billings, 1866; Catalogue Sil. Foss. Anticosti, p. 64.
—— **dentoni** Billings, 1863; Canadian Naturalist, vol. 8, p. 36, figure. Trenton.
—— **dentoni** Billings, 1865; Pal. Foss., vol. 1, p. 183, fig. 166.
—— **ecanabiæ** Hall, 1851; Rept. Geol. Lake Superior Land Dist. (Foster and Whitney), pt. 2, p. 211, pl. 27, fig. 2 a. Trenton.
—— **granti** Billings, 1865; Pal. Foss., vol. 1, p. 326, fig. 314.
—— **ottawensis** Billings, 1865; Pal. Foss., vol. 1, p. 182, fig. 165. Trenton.
Harpides Beyrich, 1846; Untersuch. Trilobiten, p. 34.
—— **atlanticus** Billings, 1865; Pal. Foss., vol. 1, p. 281, fig. 267. Quebec.
—— **concentricus** Billings, 1865; Pal. Foss., vol. 1, p. 282, fig. 268. Quebec.
—— ? **desertus** Billings, 1865; Pal. Foss., vol. 1, p. 333, fig. 321. Quebec.
Hausmannia Hall, 1888; Pal. New York, vol. 7, p. xxxi. (Subgenus, see **Dalmanites.**)
Hemicrupturus Green, 1832; Mon. Tril. N. A., p. 20.
—— *clintoni.* (See **Calymene clintoni** Vanuxem.)
Holometopus Angelin, 1854; Palæont. Scand., p. 58.
Type, *Holometopus acicularus*, pl. 33, fig. 5.
—— **angelini** Billings, 1862; Pal. Foss., vol. 1, p. 95, fig. 85; also p. 281. Quebec.
Homalonotus Koenig, 1820; Icones Foss. Sectiles, p. 4.
Type, *Homalonotus knighti* Koenig, pl. 7, fig. 85.
Syn., *Brongniartia* Eaton, 1832; Geological Text Book, p. 32, pl. 2, fig. 20 (in part).
Dipleura Green, 1832; Mon. Tril. N. A., p. 78; Monthly Am. Jour. Geology, p. 560.
Trimerus Green, 1832; Mon. Tril. N. A., p. 81; Monthly Am. Jour. Geology, p. 560.
Plœsiacomia Corda, 1847; Prodr., p. 171.
Brogniartia Salter, 1865; Mon. Brit. Tril., p. 104 (subgenus).
Burmeisteria Salter, 1865; Mon. Brit. Tril., p. 105 (subgenus).
Koenigia Salter, 1865; Mon. Brit. Tril., p. 104 (subgenus).
—— [*Asaphus*] *cornigerus* (Schlotheim) Brong., 1822; Crust. Foss., p. 18, pl. 4, fig. 10 (not pl. 2, fig. 1).
—— [*Asaphus*] **crypturus** Green, 1834; Trans. Geol. Soc. Pennsylvania, vol. 1, p. 37, pl. 4. Devonian.
—— [*Asaphus?*] **crypturus** Green, 1835; Suppl. Mon. Tril. N. A., p. 18, cast 41.
Syn., *Asaphus ditmarsiæ* Honeyman, 1879; Proc. Nova Scotia Inst., vol. 5, p. 18.
—— [*Asaphus?*] **crypturus** Honeyman, 1888; Proc. Nova Scotia Inst., vol. 7, pt. 1, p. 63.
—— **dawsoni** Hall, 1860; Canadian Naturalist, vol. 5, p. 155. Silurian.

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Homalonotus dawsoni Dawson, 1878; Acadian Geology (3d ed.), p. 606. fig. 214.

—— [*Dipleura*] **dekayi** Green, 1832; Mon. Tril. N. A.; p. 79, casts 30, 31, pl. 1, figs. 8, 9. Hamilton.

Syn., *Nuttainia sparsa* Eaton, 1832; Geological Text Book, p. 34.
Nuttainia sparsa Green, 1832; Mon. Tril. N. A., p. 89, cast 35.

—— [*Dipleura*] **dekayi** Vanuxem, 1842; Geol. New York, 3d Geol. Dist., p. 150, fig. 1.

—— [*Dipleura*] **dekayi** Hall, 1843; Geol. New York, 4th Geol. Dist., p. 205, fig. 1

—— **dekayi** Emmons, 1860; Manual Geology, pp. 146, 147, figs. 134, 135.

—— **dekayi** Hall, 1861; Des. New Species Foss, p. 85.

—— **dekayi** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 113.

—— **dekayi** Hall, 1877; Illus. Devonian Foss. Crust., pls. 2–5.

—— **dekayi** Hall, 1888; Pal. New York, vol. 7, p. 7, pl. 2, figs. 1–12; pl. 3, figs. 1–5; pl. 4, figs. 1–7; pl. 5, figs. 1–4.

—— [*Trimerus*] **delphinocephalus** Green, 1832; Monthly Am. Jour. Geol., vol. 1, p. 559, pl. 0, fig. 1. Niagara.

—— [*Trimerus*] **delphinocephalus** Green, 1832; Mon. Tril. N. A., p. 82, pl. 1, fig. 1, cast 32.

—— [*Trimerus*] **delphinocephalus** Harlan, 1835; Trans. Geol. Soc. Pennsylvania, vol. 1, p. 105.

Syn., *Brongniartia platycephala* Eaton, 1832; Geol. Text Book, p. 32, pl. 2; fig. 20.
Brongniartia platycephala Green, 1832; Mon. Tril. N. A., p. 91.
Oggyies latisima Eaton, 1832; Am. Jour. Sci., 1st seriès, vol. 21, p. 136 (footnote).

—— **delphinocephalus** Murchison, 1839; Sil. Syst., p. 651, pl. 7 *bis*, figs. 1 a, 1 b.

Syn., *Ahrendii* Roemer, 1843; Verst. Harzzebirges, p. 39, pl. 11, fig. 5.

—— **delphinocephalus** Hall, 1843; Geol. New York, 4th Geol. Dist., p. 103, fig. 34.

—— **delphinocephalus** Verneuil, Note sur la parallélisme, etc., p. 47.

Syn., *atlas* Castelnau, 1843; Syst. Sil. de l'Amér., p. 20.
giganteus Castelnau, 1843; Syst. Sil. de l'Amér.
herculaneus Castelnau, 1843; *idem*.

—— **delphinocephalus** Hall, 1852; Pal. New York, vol. 2, p. 309, pl. 68, figs. 1–14.

—— **delphinocephalus** Salter, 1865; Mon. Brit. Tril., p. 113, pl. 11, figs. 1–10.

—— **delphinocephalus** Hall, 1883; 12th Ann. Rept. Dept. Geol. Nat. Hist. Indiana, 1882, p. 332, pl. 34, figs. 17, 18.

—— **delphinocephalus** ? Hall, 1875; 28th Rept. New York State Mus. Nat. Hist., pl. 34, figs. 17, 18.

—— **delphinocephalus** Hall, 1879; 28th Rept. New York State Mus. Nat. Hist., p. 187, pl. 32, figs. 17, 18.

—— [*Trimerus*] **jacksoni** Green, 1837; Am. Jour. Sci., 1st series, vol. 32, p. 347. Devonian.

—— **major** Whitfield, 1885; Bull. Am. Mus. Nat. Hist., vol. 1, No. 6, p. 193, pl. 22. Oriskany.

—— **major** Hall, 1888; Pal. New York, vol. 7, p. 4, pl. 5 a, fig. 1.

—— **vanuxemi** Hall, 1859; Pal. New York, vol. 3, p. 352, pl. 73, figs. 9–14. Lower Helderberg.

—— **vanuxemi** Hall, 1888; Pal. New York, vol. 7, p. 11, pl. 5 b, figs. 1, 2.

Hopolichas Dames, 1877; Zeitschr. Deutsch. geol. Gesell., 1872, p. 794.

Type, *Lichas* (*Hopolichas*) *tricuspidata* Beyrich.

Illænurus Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 176.

Type, *Illænurus quadratus* Hall.

—— **convexus** Whitfield, 1878; Ann. Rept. Geol. Survey Wisconsin, 1877, p. 66. Lower Magnesian.

—— **convexus** Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 203, pl. 4, figs. 3–5.

—— **eurekensis** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 97, pl. 12, figs. 4, 4 a. Pogonip.

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Illænurus quadratus Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 176, pl. 7, figs. 52–57. Potsdam.

Illænus Dalman, 1826; Palæad., p. 50.

Type, *Illænus crassicauda*, Wahl., Nova Acta Soc. Scient. Upsal., vol. 8, p. 8, pl. 2, figs. 5, 6 (not pl. 7, figs. 5, 6, *Illænus esmarki*).

Syn., *Actinolobus* Eichwald, 1860.
Alceste Corda, 1847.
Cryptonymus Eichwald, 1825 (in part), not *Cryptonymus* Eichwald, 1840.
Deucalion Stochegloff, 1827.
Ectillænus Salter, 1866 (subgenus).
Hydrolænus Salter, 1866 (subgenus).
Illænopsis Salter, 1865 (subgenus).
Octillænus Salter, 1866 (subgenus).
Thaleops Conrad, 1843.

—— **ambiguus** Foerste, 1885; Bull. Denison Univ., vol. 1, p. 106, pl. 14, figs. 9 a, b; fig. 10 a, b, c; fig. 11. Clinton.

—— **ambiguus** Foerste, 1887; Bull. Denison Univ., vol. 2, p. 94.

—— **ambiguus** Foerste, 1886; 15th Ann. Rept. Geol. Nat. Hist. Survey Minnesota, p. 480, fig. 3.

—— **americanus** Billings, 1859; Canadian Naturalist, vol. 4, p. 371. Trenton.

—— **americanus** Billings, 1865; Pal. Foss., vol. 1, p. 329, fig. 316 a–d; fig. 318.

—— **angusticollis** Billings, 1859; Canadian Naturalist, vol. 4, p. 377, fig. 10 a–d. Trenton.

—— **arcturus** Hall, 1847; Pal. New York, vol. 1, p. 23, pl. 4 *bis*, fig. 12. Chazy and Trenton.

—— **arcturus** Emmons, 1855; Am. Geology, vol. 1, pt. 2, p. 235, pl. 3, fig. 12.

—— **arcturus** (Hall) Billings, 1859; Canadian Naturalist, vol. 4, p. 379.

—— **arcturus** Billings, 1865; Pal. Foss., vol. 1, p. 279, fig. 265.

—— **armatus** Hall, 1867; 20th Rept. New York State Cab. Nat. Hist., p. 330, pl. 22, figs. 1, 2. Niagara.

—— **armatus** Hall, 1870; 20th Rept. New York State Cab. Nat. Hist., p. 418, pl. 22, figs. 1, 2; pl. 25, fig. 22.

—— **armatus**? Hall, 1875; 28th Rept. New York State Mus. Nat. Hist., pl. 32, figs. 19, 20.

—— **armatus**? Hall, 1879; 28th Rept. New York State Mus. Nat. Hist., p. 189, pl. 32, figs. 19, 20.

—— **armatus** Hall, 1883; 12th Ann. Rept. Dept. Geol. Nat. Hist. Indiana, 1882, p. 335, pl. 34, figs. 19, 20; pl. 33, fig. 12.

—— **barriensis** (Murch.) Hall; Trans. Albany Inst., vol. 4, p. 227; abstract, p. 33, May, 1863.

—— **barriensis** (Murch.) Roemer, 1860; Die sil. Fauna W. Tennessee, p. 83, pl. 5, fig. 23. Niagara.

—— [*Bumastus*] **barriensis** (Murch.), 1839; Sil. Syst., p. 656, pl. 7 *bis*, figs. 3 a–d, pl. 14, fig. 7 (in part).

—— **barriensis** Salter, 1859; Murchison's Siluria (2d. ed.), pl. 17, figs. 9–11.

—— **bayfieldi** Billings, 1859; Canadian Naturalist, vol. 4, p. 369, figs. 4–6. Chazy.

—— **clavifrons** Billings, 1859; Canadian Naturalist, vol. 4, p. 379. Chazy and Trenton.

—— **conifrons** Billings, 1859; Canadian Naturalist, vol. 4, p. 378, figs. 7–9. Trenton.

—— *conradi* Billings, 1859; Canadian Naturalist, vol. 4, p. 372, figs. 7–9. (See **Panderia conradi**.) Trenton.

—— **consimilis** Billings, 1865; Pal. Foss., vol. 1, p. 277, figs. 263 a–c; p. 331, fig. 317. Compare *Illænus esmarki* Schlotheim. Quebec.

—— **consobrinus** Billings, 1865; Pal. Foss., vol. 1, p. 280, fig. 268; p. 332, fig. 320. Quebec.

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Illænus cornigerus Hall, 1872; 24th Rept. New York State Cab. Nat. Hist., p. 186, pl. 13, figs. 20, 21. Clinton.

—— [*Entomostracetes*] **crassicauda** Wahlenberg, 1821; Nova Acta Soc. Scient. Upsal., vol. 8, p. 27, pl. 2, figs. 5, 6 (not pl. 7, figs. 5, 6).

—— **crassicauda** Holm, 1882; Svenska Vet.-Akad. Handl., vol. 7, No. 3, pl. 2, figs. 21–27.

—— **crassicauda**? Hall, 1847; Pal. New York, vol. 1, p. 24, pl. 4 *bis*, fig. 13; pl. 60, figs. 4 a–d.

—— **crassicauda** (Wahl.) Meek and Worthen, Geol. Survey Illinois, vol. 3, p. 322, pl. 3, figs. 1 a–1 b.

Compare *Illænus consimilis* and *I. esmarckii*.

—— **cuniculus** Hall, 1867; 20th Rept. New York State Cab. Nat. Hist., p. 377, pl. 22, fig. 12. Niagara.

—— **cuniculus** Hall, 1870; 20th Rept. New York State Cab. Nat. Hist., p. 421, pl. 22, fig. 12 (rev. ed.).

—— **daytonensis** Hall and Whitfield, 1875; Pal. Ohio, vol. 2, p. 119, pl. 5, figs. 14–16. Clinton.

—— **daytonensis** Foerste, 1885; Bull. Denison Univ., vol. 1, p. 104, pl. 14, figs. 4 a, b; figs. 6, 7, 7 a, b, c.

—— **daytonensis** Foerste, 1887; Bull. Denison Univ., vol. 2, p. 93, pl. 8, figs. 1–7.

—— **fraternus** Billings, 1865; Pal. Foss., vol. 1, p. 276, figs. 262 a, b. Quebec.

—— **globosus** Billings, 1859; Canadian Naturalist, vol. 4, p. 367, figs. 1–3. Chazy.

—— [*Bumastus*] **graftonensis** Meek and Worthen, 1870; Proc. Acad. Nat. Sci. Phila., p. 54.

—— [*Bumastus*] **graftonensis** Meek and Worthen, 1875; Geol. Survey Illinois, vol. 6, p. 508, pl. 25, fig. 4.

—— **grandis** Billings, 1859; Canadian Naturalist, vol. 4, p. 380. Hudson River.

—— **herricki** Foerste, 1886; 15th Ann. Rept. Geol. Nat. Hist. Minnesota, p. 479, fig. 2. Trenton.

—— **imperator** Hall, 1861; Rept. Progress Geol. Survey Wisconsin, p. 49. Niagara.

—— **imperator** Hall, 1867; 20th Rept. New York State Cab. Nat. Hist., p. 332, pl. 22, figs. 15–17; pl. 23, figs. 2, 3.

—— **imperator** Hall, 1870; 20th Rept. New York State Cab. Nat. Hist., p. 420, pl. 22, figs. 15–17; pl. 23, figs. 2, 3.

—— **imperator** Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 306, pl. 21, figs. 4, 5.

—— **incertus** Billings, 1865; Pal. Foss., vol. 1. p. 332, fig. 319. Quebec.

—— **indeterminatus** Walcott, 1877; Advanced sheets 31st Rept. New York State Mus. Nat. Hist., p. 19. Trenton.

—— **indeterminatus** Walcott, 1879; 31st Rept. New York State Mus. Nat. Hist., p. 70.

—— **insignis** Hall, 1867; 20th Rept. New York State Cab. Nat. Hist., p. 331, figs. 5, 6, pl. 22, figs. 13, 14.

—— [*Bumastus*] **insignis** Salter, 1867; Mon. Brit. Tril., p. 207.

—— **insignis** Hall, 1867; 20th Rept. New York State Cab. Nat. Hist., p. 331, figs. 5, 6; pl. 22, figs. 13, 14.

—— **insignis** Hall, 1870; 20th Rept. New York State Cab. Nat. Hist., p. 419, figs. 10, 11; pl. 22, figs. 13, 14.

—— [*Bumastus*] **insignis** Meek, 1873; Pal. Ohio, vol. 1, p. 189, pl. 15, figs. 5 a–c.

—— **insignis** Holm, 1882; De Svenska Art. Tril. Illænus, p. 127.

—— **insignis** Whitfield, 1882; Geol. Wisconsis, vol. 4, p. 305, pl. 21, figs. 6–10.

—— **insignis** Foerste, 1886; 15th Ann. Rept. Geol. Nat. Hist. Survey Minnesota, p. 481.

—— **ioxus** Hall, 1867; 20th Rept. New York State Cab. Nat. Hist., p. 378, pl. 22, figs. 4–10. Niagara.

—— [*Bumastus*] **ioxus** Hall, 1870; 20th Rept. New York State Cab. Nat. Hist., p. 420, pl. 22, figs. 4–10.

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Illænus [*Bumastus*] **ioxus** Hall, 1883; 12th Ann. Rept. Dept. Geol. Nat. Hist. Indiana, 1882, p. 335, pl. 38, figs. 13, 14.
—— **ioxus** Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 304, pl. 21, figs. 11, 12.
—— [*Bumastus*] **ioxus** Hall, 1883; Trans. Albany Inst., vol. 10, p. 76.
—— **latidorsata** Hall, 1847; Pal. New York, vol. 1, p. 230, pl. 60, figs. 6 a, b. Trenton.
—— **madisonianus** Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 307, pl. 20, figs. 8, 9. Niagara.
—— **madisonianus** Foerste, 1885; Bull. Denison Univ., vol. 1, p. 106, pl. 14, figs. 1 a, b and 2 a, b.
—— **madisonianus** Foerste, 1887; Bull. Denison Univ., vol. 2, p. 93, pl. 8, figs. 8–10. Clinton.
—— **milleri** Billings, 1859; Canadian Naturalist, vol. 4, p. 375, fig. 10. Trenton.
—— **milleri** Walcott, 1877; Advance sheets 31st Rept. N. Y. State Mus. Nat. Hist., p. 20.
—— **milleri** Walcott, 1879; 31st Rept. N. Y. State Mus. Nat. Hist., p. 71.
—— [*Nileus*] **minnesotensis** Foerste, 1886; 15th Ann. Rept. Geol. Minnesota, p. 478, fig. 1. Trenton.
—— *niagarensis* Whitfield, 1880; Ann. Rept. Geol. Wisconsin, 1879, p. 69. Niagara.
Name changed, by request of the Wisconsin Geological Survey, from *Illænus niagarensis* to **Illænus madisonianus**. Explanation omitted by accident in the Final Report Pal. Wisconsin, p. 307.
—— **orbicaudatus** Billings, 1859; Canadian Naturalist, vol. 4, p. 379. Hudson.
—— [*Thaleops*] **ovatus** Conrad, 1843; Proc. Acad. Nat. Sci. Phila., vol. 1, p. 332. Trenton.
—— [*Thaleops* (*Illænus*)] **ovatus** Hall, 1847; Pal. New York, vol. 1, p. 259, pl. 67, figs. 6 a–b.
—— **ovatus** Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 238, pl. 5, figs. 1, 2.
—— **pomatia** Salter, 1867; Mon. Brit. Tril., pl. 27, figs. 6, 7.
—— **pterocephalus** Whitfield, 1878; Ann. Rept. Geol. Wisconsin, 1877, p. 87. Niagara.
—— **pterocephalus** Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 309, pl. 20, figs. 10–12.
—— **simulator** Billings, 1865; Pal. Foss., vol. 1, p. 337, figs. 315 a, b. Quebec.
—— **taurus** Hall, 1861; Rept. Prog. Geol. Survey Wisconsin, p. 49. Niagara.
—— **taurus** Meek and Worthen, 1865; Geol. Survey Illinois, vol. 3, p. 320, pl. 3, fig. 2.
—— [*Bumastus*] **trentonensis** Emmons, 1842; Geol. New York, 3d Geol. Dist., p. 390 fig. 1. Trenton.
—— [*Bumastus*] **trentonensis**, 1854; 7th Rept. New York State Cab. Nat. Hist., p. 64, fig. 1.
—— [*Bumastus*] **trentonensis** Emmons, 1855; Am. Geology, vol. 1, pt. 2, p. 215, pl. 15, fig. 13.
—— **trentonensis** Hall, 1847; Pal. New York, vol. 1, p. 230, pl. 60, fig. 5.
—— **tumidifrons** Billings, 1865; Pal. Foss., vol. 1, p. 278, fig. 264. Quebec.
—— **vindex** Billings, 1865; Pal. Foss., vol. 1, p. 179, fig. 160. Chazy.
—— [*Bumastus*] **worthenanus** Winchell and Marcy, 1866; Mem. Boston Soc. Nat. Hist., vol. 1, pt. 1, p. 105, pl. 3, fig. 13 (referred by Hall, 20th Rept. New York State Cab. Nat. Hist., to *Illænus armatus* Hall).

Isoletus De Kay, 1825; Annals Lyceum Nat. Hist. New York, vol. 1, p. 174.
—— *canalis*. (See **Asaphus canalis**.)
—— *cyclops*. (See **Asaphus platycephalus**.)
—— *gigas*. (See **Asaphus platycephalus**.)
—— *maximus*. (See **Asaphus maximus**.)
—— *megalops* Green, 1832; Mon. Tril. N. A., p. 70, cast 75.
—— *megistos*. (See **Asaphus maximus**.)
—— *platycephalus*. (See **Asaphus platycephalus**.)
—— *planus*. (See **Asaphus platycephalus**.)

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Isoletus stegops. (See **Asaphus platycephalus.**)
—— *vigilans*. (See **Asaphus vigilans.**)
Lichas Dalman, 1826; Palæad., pp. 53, 71, pl. 6, fig. 1.
Type, *Lichas laciniatus* Wahlenberg.
Syn., *Platynotus* Conrad, 1838; Geol. Survey New York, Rept. Pal. Dept., p. 118.
Arges Goldfuss, 1839 (in part).
Metopias Eichwald, 1842; Die Urwelt Russ., p. 62, pl. 3, figs. 21–23.
Actinurus Castelnau, 1843; Syst. Sil. de l'Amér., p. 21.
Nuttainia Portlock and Emmrich.
Corydocephalus Corda, 1847; Prodr., p. 255.
Dicranopeltis Corda, 1847; Prodr., p. 257.
Acanthopyge Corda, 1847; Prodr., p. 260.
Dicranoymus Corda, 1847; Prodr., p. 261.
Subgenera, *Hoplolichas* Dames, 1877; Zeitschr. Deutsch. geol. Gesellsch., 1877, p. 794.
Type, *Hoplolichas tricuspidata* Beyrich.
Conolichas Dames, 1877; Zeitschr. Deutsch. geol. Gesellsch., 1877, p. 806.
Type, *Conolichas æquiloba* Steinhardt.
—— *armatus* Hall. (See **Acidaspis eriopis** Hall.)
—— **bigsbyi** Hall, 1859; Pal. New York, vol. 3, p. 364, pl. 77, figs. 1–8.
Lower Helderberg.
—— [*Conolichas*] **bigsbyi?** Hall, 1888; Pal. New York, vol. 7, p. 80, pl. 19 a, fig. 1.
—— [*Paradoxides*] **boltoni** Bigsby, 1825; Jour. Acad. Nat. Sci. Phila., vol. 4, p. 365, plate. Niagara.
—— [*Paradoxides*] **boltoni** Green, 1832; Monthly Am. Jour. Geol., etc., vol. 1, p. 560, pl. 1, fig. 5.
—— [*Paradoxides*] **boltoni** Green, 1832; Mon. Tril. North America, p. 60, pl. 1, fig. 5.
—— [*Paradoxides*] **boltoni** Harlan, 1834; Trans. Geol. Soc. Penn., vol. 1, p. 103.
—— [*Paradoxides*] **boltoni** Harlan, 1835; Med. and Phys. Researches, p. 303.
—— [*Platynotus*] **boltoni** Conrad, 1838; Rept. Pal. Dept. Geol. Survey New York, p. 118.
—— [*Actinurus*] **boltoni** Castelnau, 1843; Syst. Sil. de l'Amér., p. 21, pl. 3, fig. 3.
—— **boltoni** Hall, 1852; Pal. New York, vol. 2, p. 311, pl. 69; pl. 70, figs. 1 a–i.
—— **boltoni** Meek and Worthen, 1875; Geol. Survey Illinois, vol. 6, p. 508, pl. 25, fig. 5.
—— **boltoni** var. **occidentalis** Hall, 1863; Trans. Albany Inst., vol. 4, p. 223; abstract, p. 29.
—— **boltoni** var. **occidentalis** Hall, 1875; 28th Rept. New York State Mus. Nat. Hist. Expl., p. 34, figs. 8–11.
—— **boltoni** var. **occidentalis** Hall, 1879; 28th Rept. New York State Mus. Nat. Hist., p. 198, pl. 34, figs. 8–11.
—— **boltoni** var. **occidentalis** Hall, 1883; 12th Ann. Rept. Dept. Geol. Nat. Hist. Indiana, 1882, p. 334, pl. 36, figs. 8, 11, 12 (?).
—— **breviceps** Hall, 1863; Trans. Albany Inst., vol. 4, p. 222; abstract, p. 28.
Niagara.
—— **breviceps** Hall and Whitfield, 1875; Pal. Ohio, vol. 2, p. 156, pl. 6, fig. 17.
—— **breviceps** Hall, 1875; 28th Rept. New York State Mus. Nat. Hist. Expl., pl. 34, figs. 1–7.
—— **breviceps** Hall, 1879; 28th Rept. New York State Mus. Nat. Hist., p. 197, pl. 34, figs. 1–7.
—— **breviceps** Hall, 1883; 12th Ann. Rept. Dept. Geol. Nat. Hist. Indiana, 1882, p. 343, pl. 36, figs. 1–7.
—— **breviceps** Foerste, 1885; Bull. Denison Univ., vol. 1, p. 112, pl. 13, figs. 2, 6 a, b.
Clinton.

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Lichas breviceps Foerste, 1887; Bull. Denison Univ., vol. 2, p. 98, pl. 8, figs. 18, 19. Not *Lichas breviceps* Hall, 1867; 20th Rept. New York State Cab. Nat. Hist., p. 377, pl. 21, figs. 12–14; also rev. ed., p. 424, pl. 21, figs. 12–14. (See **Lichas emarginatus.**)

— **canadensis** Billings, 1866; Catalogue Sil. Foss. Anticosti, p. 65, fig. 22.

— **champlainensis** Whitfield, 1886; Bull. Am. Mus. Nat. Hist. New York, vol. 1, No. 8, p. 342, pl. 23, figs. 6–8. Birdseye.

— [*Arges*] **contusus** Hall, 1888; Pal. New York, vol. 7, p. 83, pl. 19 b, figs. 3–6. Upper Helderberg.

— **cucullus** Meek and Worthen, 1865; Proc. Acad. Nat. Sci. Phila., p. 266. Trenton.

— **cucullus** Meek and Worthen, 1866; Geol. Survey Illinois, vol. 3, p. 299, pl. 1, figs. 6 a–c.

— **decipiens** Winchell and Marcy, 1866; Mem. Boston Soc. Nat. Hist., vol. 1, pt. 1, p. 104, pl. 3, fig. 11. Niagara.

— [*Ceratolichas*] **dracon** Hall, 1888; Pal. New York, vol. 7, p. 85, pl. 19, figs. 14–17. Hall, 1876; Illus. Devonian Foss. Crust., pl. 19, figs. 2, 3. Upper Helderberg.

— **emarginatus** Hall, 1879; 28th Rept. New York State Mus. Nat. Hist., p. 199. Niagara.

Syn., *Lichas breviceps* Hall; 20th Rept. New York State Cab. Nat. Hist., p. 377, pl. 21, figs. 12–14, rev. ed., p. 424, pl. 21, figs. 12–14.

— **eriopis**, Hall. Upper Helderberg.

Syn., *Lichas armatus* Hall, 1861; Des. New Species Foss., p. 81.
Lichas armatus Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 109.

— **eriops** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 226.

— [*Acidaspis* (*Teratasp*is)] **eriops** Hall, 1876; Illus. Devonian Foss. Crust., pl. 19, figs. 4–7, 10, 11.

— [*Acidaspis* (*Teratasp*is?)] **sp.?** Hall, 1876; Illus. Devonian Foss. Crust., pl. 19, fig. 12.

— [*Conolichas*] **eriops** Hall, 1888; Pal. New York, vol. 7, p. 78, pl. 19 a, figs. 2–13, 15, 16.

— **grandis** Hall, 1861; Des. New Species Foss., p. 82. Upper Helderberg.

— **grandis** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 110.

— **grandis** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 223. (Subgenus *Teratasp*is.)

Syn., *superbus* Billings, 1875; Canadian Naturalist, vol. 7, p. 239.

— [*Acidaspis* (*Teratasp*is)] **grandis** Hall, 1876; Illus. Devonian Foss. Crust., pls. 17, 18.

— [*Teratasp*is] **grandis** Hall, 1888; Pal. New York, vol. 7, p. 73, pl. 17, figs. 1–6; pl. 18, figs. 1, 2; pl. 19, figs. 1–7.

— [*Ceratolichas*] **grandis** Hall, 1888; Pal. New York, vol. 7, p. 84, pl. 19 b, figs. 7–13.

— [*Ceratolichas*] **gryps** Hall, 1888; Pal. New York, vol. 7, p. 84, pl. 19 b, figs. 7–13.

— **harrisi** Miller, 1878; Jour. Cincinnati Soc. Nat. Hist., vol. 1, p. 106, pl. 3, fig. 9. Hudson.

— [*Acidaspis* n. sp.?] Hall, 1876; Illus. Devonian Foss. Crust., pl. 19, fig. 1 (not figs. 2, 3). Upper Helderberg.

— [*Conolichas*] **hispidus** Hall, 1888; Pal. New York, vol. 7, p. 77, pl. 19 a, figs. 14, 17, 18.

Syn., [*Acidaspis* (*Teratasp*is)] *eriops* Hall, 1876; Illus. Dev. Foss., pl. 19, figs. 8, 9. Upper Helderberg.

— [*Hoplolichas*] **hylæus** Hall, 1888; Pal. New York, vol. 7, p. 81, pl. 19 b, figs. 1, 2. Upper Helderberg.

— **jukesi** Billings, 1865; Pal. Foss., vol. 1, p. 282, fig. 260; also p. 335, fig. 323. Quebec.

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Lichas minganensis Billings, 1865; Pal. Foss., vol. 1, p. 181, figs. 163 a, b. Chazy and Trenton.

—— **nereus** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 226. Niagara.

—— **obvius** Hall, 1870; 20th Rept. New York State Cab. Nat. Hist., p. 424, pl. 25, fig. 19. Niagara.

—— [*Calymene*] **phlyctanodes** Green, 1837; Am. Jour. Sci., 1st series, vol. 32, p. 167. Niagara.

—— [*Arges*] **phlyctanodes** Hall, 1852; Pal. New York, vol. 2, p. 314, pl. 70, figs. 2 a, c.

—— [*Dicranogmus*] **ptyonurus** Hall, 1888; Pal. New York, vol. 7, p. 86, pl. 19 b, figs. 19–21. Niagara.

—— **pugnax** Winchell and Marcy, 1866; Mem. Boston Soc. Nat. Hist., vol. 1, pt. 1, p. 103, pl. 3, fig. 10. Niagara.

—— **pugnax** Hall, 1867; 20th Rept. New York State Cab. Nat. Hist., p. 393 (rev. ed., p. 424, pl. 25, fig. 20).

—— **pustulosus** Hall, 1859; Pal. New York, vol. 3, p. 366, pl. 77, figs. 9–12; pl. 78, figs. 1–6, fig. 7 (?). Lower Helderberg.

—— **pustulosus** Hall, 1876; Illus. Devonian Foss. Crust., pl. 19, fig. 13.

—— [*Conolichas*] **pustulosus** Hall, 1888; Pal. New York, vol. 7, p. 80, pl. 19, figs. 8, 10, 11.

—— *superbus* Billings, 1875; Canadian Naturalist, n. s., vol. 7, p. 239. (See **Lichas grandis.**) Corniferous.

—— [*Asaphus?*] **trentonensis** Conrad, 1842; Jour. Acad. Nat. Sci. Phila., vol. 8, p. 277, pl. 16, fig. 16. Trenton.

—— [*Platynotus*] **trentonensis** Hall, 1847; Pal. New York, vol. 1, p. 235, pl. 64, figs. 1 a–e.

—— **trentonensis** Miller, 1874; Cincinnati Quart. Jour. Sci., vol. 1, p. 127.

Lloydia Vogdes, 1889 (generic name for *Bathyurus bituberculatus* Billings for its type).

Loganellus Devine, 1863; Canadian Naturalist, vol. 8, p. 95. (See **Ptychoparia, Crepicephalus,** and **Olenus.**)

—— *logani* Devine, 1863; Canadian Naturalist, vol. 8, p. 95. (See **Ptychoparia logani.**)

—— [*Olenus?*] *logani* Billings, 1865; Pal. Foss., vol. 1, p. 201, figs. 185, 186.

—— *quebecensis* Billings, 1865; Pal. Foss., vol. 1, p. 203. (See **Ptychoparia logani.**)

Lonchocephalus Owen, 1852; Rept. Geol. Survey Wisconsin, Iowa, and Minnesota, p. 576. (See **Anomocare hamulus** (Owen) Dames.)

Megalaspis Angelin, 1852; Palæont. Scand., p. 15.

Type, *Megalaspis gigas* Ang., pl. 12, fig. 3.

—— **belemnurus** White, 1874; Rept. Invert. Foss., etc., p. 11. Quebec.

—— **belemnurus** White, 1877; Geog. Sur. W. 100th Meridian, Pal., vol. 4, p. 59, pl. 3, fig. 9.

—— [*Asaphus* (*meglaspis*)] **goniocerus** Meek, 1873; 6th Ann. Rept. Geol. Survey Territories, 1872, p. 480. Quebec.

Menocephalus Owen, 1852; Rept. Geol. Survey Wisconsin, Iowa, and Minnesota, p. 577.

Dr. D. D. Owen refers one species to this genus, *Menocephalus minnesotensis*, pl. 1, fig. 11, which has a highly arched and hemispherical glabella.

—— **globosus** Billings, 1860; Canadian Naturalist, vol. 5, p. 317, figs. 17–19. Quebec.

—— **globosus** Billings, 1865; Pal. Foss., vol. 1, p. 408, figs. 388 a–c.

—— **minnesotensis** Owen, 1852; Rept. Geol. Survey Wisconsin, Iowa, and Minnesota, p. 577, pl. 1, fig. 11. Cambrian.

—— **salteri** Billings, 1863; Canadian Naturalist, vol. 8, p. 210, figure. Cambrian.

—— **salteri** Billings, 1865; Pal. Foss., vol. 1, p. 203, fig. 187.

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Menocephalus salteri ? Rominger, 1888; Proc. Acad. Nat. Sci. Phila., pl. 16, pl. 1, fig. 6.

—— **sedgwicki** Billings, 1860; Canadian Naturalist, vol. 5, p. 316, fig. 16. Quebec.

—— **sedgwicki** Billings, 1865; Pal. Foss., vol. 1, p. 407, fig. 387.

Mesonacis Walcott, 1885; Am. Jour. Sci., 3d series, vol. 29, p. 329.

—— [*Olenus*] **vermontana** Hall, 1859; 12th Rept. New York State Cab. Nat. Hist., p. 60, figure. Cambrian.

—— [*Olenus*] **vermontana** Hall, 1859; Pal. New York, vol. 3, p. 527, figure.

—— [*Paradoxides*] **vermonti** Emmons, 1860; Manual Geology, p. 280 (note A).

—— [*Paradoxides*] **vermontana** Barrande, 1861; Bull. Soc. Géol. France, 2d series, vol. 18, p. 277, pl. 5, fig. 8.

—— [*Paradoxides*] **vermontana** Billings, 1861; Geology Vermont, vol. 2, p. 950.

—— [*Barrandia*] **vermontana** Hall, 1861; 13th Rept. New York State Cab. Nat. Hist., p. 117, figure.

—— [*Barrandia*] **vermontana** Hall, 1861; Geol. Vermont, vol. 1, p. 370, pl. 13, figs. 2, 4, and 5.

—— [*Paradoxides*] **vermontana** Billings, 1863; Geol. Canada, p. 953.

—— [*Olenellus*] **vermontana** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 114.

—— [*Olenellus*] **vermontana** Billings, 1865; Pal. Foss., vol. 1, p. 10.

—— [*Olenellus*] **vermontana** Whitfield, 1884; Bull. Am. Mus. Nat. Hist. New York, vol. 1, p. 152, pl. 15, figs. 2–4.

—— **vermontana** Walcott, 1885; Am. Jour. Sci., 3d series. vol. 29, p. 329, figs. 1, 2.

—— **vermontana** Walcott, 1885; Nature, vol. 32, p. 68.

—— **vermontana** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 158, pl. 24, figs. 1 a, b.

Microdiscus Emmons, 1855; Am. Geology, vol. 1, pt. 2, p. 116.

Type, *Microdiscus speciosus* Ford.

—— **belli-marginatus** Shaler and Foerste, 1888; Bull. Mus. Comp. Zool. Harvard Coll., vol. 16, p. 35, pl. 2, fig. 19. Cambrian.

—— **connexus** Walcott, 1887; Am. Jour. Sci., 3d series, vol. 34, p. 194, pl. 1, figs. 4–4 b. Cambrian.

—— **dawsoni** Hartt, 1868; Acadian Geology, p. 654, fig. 228. St. John.

Mr. Hartt originally described this species under the new generic name of *Dawsonia*, but on Mr. E. Billings's authority the species was referred to *Microdiscus* in the Acadian Geology.

—— **dawsoni** Whiteaves, 1878; Am. Jour. Sci., 3d series, vol. 16, p. 225.

—— **dawsoni** Walcott, 1884; Bull. U. S. Geol. Survey, No. 10, p. 23, pl. 2, figs. 3, 3 a.

—— [*Agnostus*] **lobatus** Hall, 1847; Pal. New York, vol. 1, p. 258, pl. 67, figs. 5 a–f. Potsdam.

—— [*Agnostus*] **lobatus** Rogers, 1858; Geol. Survey Pennsylvania, vol. 2, p. 820, fig. 614 (1–4).

—— **lobatus** Ford, 1873; Am. Jour. Sci., 3d series, vol. 6, p. 135 (foot-note).

—— **lobatus** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 156, pl. 16, figs. 1, 1 a, b.

—— **lobatus** Shaler and Foerste, 1888; Bull. Mus. Comp. Zool. Harvard Coll., vol. 16, p. 36, pl. 2, fig. 13.

—— **meeki** Ford, 1876; Am. Jour. Sci., 3d series, vol. 11, p. 371. Lower Potsdam.

—— **meeki** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 155, pl. 16, fig. 4.

—— **parkeri** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 157, pl. 16, figs. 2, 2 a. Middle Cambrian.

—— **pulchellus** (Hartt MS.) Walcott, 1884; Bull. U. S. Geol. Survey, No. 10, p. 24. St. John.

—— **punctatus** Salter, 1864; Quart. Jour. Geol. Soc. London, vol. 20, p. 237, pl. 13, fig. 11. St. John.

—— **punctatus** Whiteaves, 1878; Am. Jour. Sci., 3d series, vol. 16, p. 225.

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Microdiscus punctatus Walcott, 1884; Bull. U. S. Geol. Survey, No. 10, p. 24, pl. 2, figs. 1, 1 a–c.

—— **quadricostatus** Emmons, 1855; Am. Geology, vol. 1, pt. 2, p. 116, pl. 1, fig. 8. Taconic.

—— **quadricostatus** Emmons, 1860; Manual Geology, p. 88, fig. 73.

—— **quadricostatus** Barrande, 1861; Bull. Soc. Géol. France, 2d series, vol. 18, p. 280, pl. 5, figs. 13 a, b.

—— **speciosus** Ford, 1873; Am. Jour. Sci., 3d series, vol. 6, p. 137, figs. 2 a, b. Potsdam.

—— **speciosus** Ford, 1877; Am. Jour. Sci., 3d series, vol. 13, p. 147.

—— **speciosus** Ford, 1879; New York Tribune Extra, Sept. 2, 1879, fig. 2.

—— **speciosus** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 154, pl. 16, figs. 3, 3 a–c.

Nileus Dalman, 1826; Palæad., p. 246 (German trans., p. 49).

Type, *Nileus armadillo* Dalman.

—— **affinis** Billings, 1865; Pal. Foss., vol. 1, p. 275, figs. 261 a, b. Quebec.

—— **macrops** Billings, 1865; Pal. Foss., vol. 1, p. 273, fig. 259. Quebec.

—— **scrutator** Billings, 1865; Pal. Foss., vol. 1, p. 274, fig. 260. Quebec.

Nuttania Eaton, 1832 (in part); Geological Text Book, p. 33. (See **Trinucleus** and **Homalonotus**.)

—— *concentrica* Eaton, 1832; Geological Text Book, p. 34, pl. 1, fig. 2.

—— *sparsa* Eaton, 1832; Geological Text Book, p. 34.

Odontocephalus Conrad, 1840; 3d Ann. Rept. Pal. Dept. New York Geol. Survey, p. 204.

—— [*Dalmanites* (*Odontocephalus*)] Hall and Clarke, 1888; Pal. New York, vol. 7, p. xxxiii.

I can not do justice to this genus without giving a brief historical sketch, which dates back to 1781. During this year M. T. Brünnich (Beskrivelse over Trilobiten, Nye Samling af det Kong. Danske Vidensk. Skrifter, vol. 1, p. 392, pl. 0, figs. 1, 2) published a description of a fossil Trilobite from Coalbrook Dale under the name of *Trilobus caudatus*. As this Trilobite in after years had many generic names, I give a translation of the original description for the use of students. The author figures the head and pygidium of *Trilobus caudatus* and remarks: "As I was not fortunate enough to obtain a complete specimen of the entirely unknown fossil, but only broken parts, I can not distinctly describe its size or number of rings; however, the annexed figures show the distinct features of this species and their peculiar morphology. The size of the fossil at its anterior bend is 1¼ inches, the front piece outside of the crust is ¼ inch, its total length 34 inches; the broken back part, consisting of about sixteen rings, is 1 inch in length to the tail, the latter being 1 inch long. The head shield is surrounded by a flat-shaped edge, which terminates in an upright protuberance with a tongue rounded anteriorly. The shell shows various elevations separated by transverse furrows. The eyes on the side of the shell are very protruding, semilunar in form, and faceted after the eyes of insects. On the head-shield may be seen some small nodes, which are also visible on the first ring and on some of the others. The tail diminishes in breadth and terminates in a narrow, long, and pointed projection."

The first systematic writer (Brongniart, Crust. Foss., p. 22) included this species under his genus *Asaphus*, and it was so classified until 1844, when Dr. H. F. Emmrich (Zur Morphologie der Trilobiten, p. 15, pl. 1, fig. 1) proposed the new generic term of *Dalmania* for it. Unfortunately this term was then preoccupied for a genus of the Diptera. Dr. H. F. Emmrich's work was well known in Europe, having appeared in two separate German editions, and also in English (Scient. Mem., vol. 4, pt. 14, 1847).

In the year 1847 A. J. C. Corda (Prodr., p. 208, pl. 5, fig. 56) changed Emmrich's generic name to *Odontochile*, a preoccupied term in natural history. This name

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was only used by one other author (McCoy, Annals Nat. Hist., London, vol. 4, 1849), all others using *Dalmania* or its modified form, *Dalmanites* (Barrande).

In 1840 Milne-Edwards (Crust., pp. 306, 339) proposed the name of *Pleuracanthus* for *Calymene arachnoides* Goldfuss, and Dr. Goldfuss that of *Acaste* (Neues Jahrbuch für Mineral., 1843, p. 511) for such forms as *Calymene downingiæ* Murch.

In America a typical species (*Dalmanites limulurus*) has been classed by all American writers either under *Dalmania* or its modified form, but other species properly of this genus—that is, if we do not desire to overburden generic classification—have been given new generic names. The first was an obscure fossil described by Dr. Jacob Green (Am. Jour. Sci., 1st series, vol. 32, p. 343) as *Cryphæus boothi*, a generic term preoccupied for a genus of the Coleoptera at the time it was used by Dr. Green. The second species consists of a poorly figured tail, described and figured by Prof. Amos Eaton (Geological Text Book, p. 31, pl. 1, fig. 1) as *Asaphus selenurus*, and by Dr. Jacob Green under the name of *Calymene odontocephala* (Am. Jour. Sci., 1st series, vol. 25, p. 334). Prof. Amos Eaton's description was drawn from the tail of the fossil and Dr. Jacob Green's from the head.

Mr. T. A. Conrad in 1840 (3d Ann. Rept. Pal. Dept. New York Geol. Survey, p. 204) procured a perfect specimen of this Trilobite and united the two species under a new generic name, *Odontocephalus selenurus*, taking Dr. Jacob Green's specific name for the genus, and that of Prof. Amos Eaton for the species.

The generic characteristics consist of a series of incisor-like denticulations bordering the frontal margin of the head, and a pygidium with two terminal spines.

Hall and Clarke (1888, Pal. New York, vol. 7, p. xxxiii) use the term as a subgenus to *Dalmanites*.

If we follow the strict rule of priority and set aside the preoccupied name *Dalmania* or *Dalmanites* for that of *Odontocephalus* Conrad, we take for a generic name a term indicating a denticulated cephalic shield, which is confined to a special group and miscall such species as the well known type *Dalmanites caudatus*.

We would therefore suggest, not only in honor of the learned Swedish author on Trilobites, but also through courtesy, that the generic name of *Dalmanites* be retained.

Odontocephalus. (See **Dalmanites** [*Odontocephalus*] **selenurus**, **D.** [*Odontocephalus*] **bifidens**, **D.** [*Odontocephalus*] **ægeria**, and **D.** [*Odontocephalus*] **coronatus**.

Ogygia Brongniart, 1822; Crust. Foss., p. 26.

Type, *Asaphus buchii* Brongniart, pl. 2, figs. 3 a–c.

—— [*Asaphus*] **barrandi** Hall, 1851; Rept. Geol. Lake Superior Land Dist. (Foster and Whitney), pt. 2, p. 210, pl. 27, figs. 1 a–d; pl. 28. Birdseye.

—— [*Asaphus*] **barrandi** Hall, 1862; Geol. Wisconsin, vol. 1, p. 41, fig. 4.

—— **klotzi** Rominger, 1887; Proc. Acad. Nat. Sci. Phila., p. 12, pl. 1, fig. 1. Cambrian.

—— **klotzi** Walcott, 1888; Am. Jour. Sci., 3d series, vol. 36, p. 166.

—— [*Ogygies*] *latissimus* Eaton, 1832; Am. Jour. Sci., vol. 21, p. 136, foot-note.

—— [*Ogyges*] *latissimus* Eaton, 1832; Geol. Text Book, p. 33 (**Homalonotus delphinocephus**).

—— **parabola** Hall and Whitfield, 1877; U. S. Geol. Expl. 40th Par., vol. 4, p. 245, pl. 2, fig. 35. Cambrian.

—— ? **problematica** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 63, pl. 10, figs. 2 a, b and 4. Cambrian.

—— **producta** Hall and Whitfield, 1877; U. S. Geol. Expl. 40th Par., vol. 4, p. 234, pl. 2, figs. 31–34; also p. 245, pl. 2, fig. 35. Cambrian.

—— [*Niobe*] **producta** Brögger, 1886; Om alderen af Olenellus zonæ i Nordamerika, p. 211.

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Ogygia [*Bathyuriscus*] **productus** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 217, pl. 30, figs. 1, 1 a–i.
Syn., *Ogygia parabola* (H. & W.) Walcott, 1886; *idem.*, p. 217.
—— **serrata** Rominger, 1887; Proc. Acad. Nat. Sci. Phila., p. 13, pl. 1, figs. 2, 2 a. Cambrian.
—— ? *spinosa* Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 63, pl. 9, fig. 22. (See **Olenoides spinosa** Walcott.)
—— **vetustus** Hall, 1847; Pal. New York, vol. 1, p. 227, pl. 60, fig. 1. Trenton.
—— **vetustus** Emmons, 1855; American Geology, vol. 1, pt. 2, p. 216, fig. 72.
Olenellus Hall, 1861; Des. N. Species of Foss., published in advance, 15th Rept. State Cab., p. 86. Hall, 1862; 15th Rept. State Cab. Nat. Hist. Albany, p. 114.
Type, *Olenellus thompsoni* Hall.
—— [*Elliptocephala*] **asaphoides** Emmons, 1844; Taconic System, p. 21, figs. 1–3. Cambrian.
—— [*Elliptocephala*] **asaphoides** Emmons, 1846; Agric. New York, vol. 1, p. 65, figs. 1–3.
—— [*Olenus*] **asaphoides** Hall, 1847; Pal. New York, vol. 1, p. 256, pl. 67, figs. 2 a, c.
—— [*Olenus*] **asaphoides** Fitch, 1849; Trans. N. Y. State Agric. Soc., vol. 9, p. 865.
—— [*Elliptocephalus*] **asaphoides** Emmons, 1849; Proc. Am. Assoc. Adv. Sci., 1st meeting, p. 18.
—— [*Eliptocephalus*] **asaphoides** Emmons, 1855; Am. Geology, vol. 1, pt. 2, p. 114, figs. 1–3, pl. 1, fig. 18.
—— [*Paradoxides*] **asaphoides** Emmons, 1860; Manual Geology, pp. 87, 280.
—— [*Paradoxides*] **asaphoides** Barrande, 1861; Bull. Soc. Géol. France, 2d series, vol. 18, p. 273, pl. 5, figs. 4, 5.
—— [*Olenus*] **asaphoides** Ford, 1871; Am. Jour. Sci., 3d series, vol. 2, p. 33.
—— [*Elliptocephalus*] **asaphoides** Ford, 1877; Am. Jour. Sci., 3d series, vol. 13, p. 266, plate, figs. 1–10.
—— [*Elliptocephalus*] **asaphoides** Ford; Am. Jour. Sci., 3d series, vol. 15, p. 129.
—— **asaphoides** Ford, 1881; Am. Jour. Sci., 3d series, vol. 22, p. 250.
—— **asaphoides** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 168, pl. 17, figs. 4, 8, 10; pl. 20, figs. 3, 3 a, b; pl. 25, fig. 8.
—— **gilberti** (Meek MS.) White, 1874; Prelim. Rept. Invt. Foss. U. S. Geog. and Geol. Survey West 100th Mer., p. 7. Potsdam.
—— [*Olenus*] **gilberti** Gilbert, 1875; U. S. Geog. Survey West 100th Mer., vol. 3, p. 182.
—— **gilberti** White, 1877; U. S. Geog. Survey West 100th Mer., vol. 4, p. 44, pl. 2, figs. 1, 3 a–e.
—— **gilberti** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 29, pl 9, figs. 16, 16 a; pl. 21, fig. 13.
—— **gilberti** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 170, pl. 18, figs. 1, 1 a–c; pl. 19, fig. 2, 2 a–k; pl. 20, figs. 1, 1 a, 1 b, 4.
—— **howelli** (Meek MS.) White, 1874; Prelim. Rept. Invt. Foss. U. S. Geog. and Geol. Survey West 100th Mer., p. 8. Potsdam.
—— [*Olenus*] **howelli** Gilbert, 1875; U. S. Geog. Survey West 100th Mer., vol. 3, p. 183.
—— **howelli** White, 1877; U. S. Geog. Survey West 100th Mer., vol. 4, p. 47, pl. 2, figs. 4 a, b.
—— **howelli** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, pp. 29, 30, pl. 9, figs. 15 a–b, 16–16 a; pl. 21, figs. 1–9.
—— **iddingsi** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 28, pl. 9, fig. 12. Cambrian.
—— **iddingsi** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 170, pl. 19, fig. 1.
—— [*Paradoxides*] **macrocephalus** Emmons, 1860; Manual Geology, p. 88, fig. 70.
—— [*Olenus*] **thompsoni** Hall, 1859; 12th Rept. New York State Cab. Nat. Hist., p. 57, figure. Cambrian.

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Olenellus [*Olenus*] **thompsoni** Hall, 1859; Pal. New York, vol. 3, p. 525, figure.
—— [*Barrandia*] **thompsoni** Hall, 1860; 13th Rept. New York State Cab. Nat. Hist., p. 116, figure.
—— [*Paradoxides*] **thompsoni** Emmons, 1860; Manual Geology, p. 280, note A.
—— [*Paradoxides*] **thompsoni** Barrande, 1861; Bull. Soc. Géol. France, 2d series, vol. 18, p. 276, pl. 5, fig. 6.
—— [*Paradoxides*] **thompsoni** Billings, 1861; Geol. Vermont, vol. 2, p. 950.
—— [*Barrandia*] **thompsoni** Hall, 1861; Geol. Vermont, vol. 2, p. 369, pl. 13, fig. 1.
—— [*Paradoxides*] **thompsoni** Billings, 1861; Pal. Foss., vol. 1, p. 11 (pamphlet published in advance).
—— **thompsoni** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist, p. 114.
—— **thompsoni** Billings, 1863; Geol. Canada, p. 953.
—— [*Olenellus*] **thompsoni** Billings, 1865; Pal. Foss., vol. 1, p. 11.
—— **thompsoni** Whitfield, 1884; Bull. Am. Mus. Nat. Hist., New York, vol. 1, p. 151 pl. 15, figs. 1–4.
—— **thompsoni** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 167, pl. 17, figs. 1, 2, 4, 9; pls. 22, 23, figure.
—— *vermontana.* (See **Mesonacis vermontana** (Hall) Walcott.)

Olenoides Meek, 1877; U. S. Geol. Expl. 40th Par., Pal., vol. 4, p. 25.
Type, *Olenoides nevadensis* Meek.
—— **fordi** Walcott, 1887; Am. Jour. Sci., 3d series, vol. 34, p. 195, pl. 1, figs. 5, 5 b. Cambrian.
—— *flagricaudus.* (See **Zacanthoides flagricaudus.**)
—— *levis* Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 187, pl. 25, figs. 3–3 a. (See **Zacanthoides levis.**) Cambrian.
—— *gothicus* (Hall and Whitfield) Walcott. (See **Dorypyge gothicus.**)
—— ? **marcoui** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 186, pl. 26, fig. 5–5 a, b.
—— [*Dikellocephalus ?*] **marcoui** Whitfield, 1884; Bull. Am. Mus. Nat. Hist. New York, vol. 1, p. 150, pl. 14, fig. 7. Cambrian.
—— [*Paradoxides ?*] **nevadensis** Meek, 1870; Proc. Acad. Nat. Sci. Phila., vol. 22, p. 62. Middle Cambrian.
—— [*Paradoxides ?*] **nevadensis** Meek, 1877; U. S. Geol. Expl. 40th Par., Pal., vol. 4, p. 23, pl. 1, fig. 5.
—— **nevadensis** Meek, 1877; U. S. Geol. Expl. 40th Par., Pal., vol. 4, p. 25.
—— **nevadensis** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 181, pl. 25, fig. 7.
—— **nevadensis** Walcott, 1888; Am. Jour. Sci., 3d series, vol. 36, p. 165.
Syn., *Ogygia serrata* (Rominger) Walcott, 1888; Am. Jour. Sci., 3d series, vol. 36, p. 165.
—— [*Olenoides*] *quadriceps* (Hall and Whitfield) Walcott. (See **Dorypyge quadriceps.**)
—— *spinosus.* (See **Zacanthoides spinosus.**)
—— *typicalis.* (See **Zacanthoides typicalis.**)
—— [*Dikellocephalus*] **wahsatchensis** Hall and Whitfield, 1877; U. S. Geol. Expl. 40th Par., Pal., vol. 4, p. 241, pl. 1, fig. 35.
—— **wahsatchensis** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 189, pl. 29, figs. 2, 2 a. Middle Cambrian.
Syn., [*Dikellocephalus ?*] *gothicus* (Hall and Whitfield) Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 189.
—— **wahsatchensis** Walcott, 1888; Am. Jour. Sci., 3d series, vol. 36, p. 165.

Olenus Dalman, 1826; Palæad, p. 226.
Type, *Olenus gibbosus* Wahlenberg.
—— *asaphoides.* (See **Olenellus asaphoides.**)
—— *holopyga.* (See **Bathynotus holopyga.**)
—— *logani.* (See **Ptychoparia logani.**)

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Olenus *thompsoni*. (See **Olenellus thompsoni**.)
—— **undulostriatus** Hall, 1847; Pal. New York, vol. 1, p. 258, pl. 67, figs. 3 a, b. Hudson.
—— **utahensis** Woodward, 1873; Rept. 43d Meeting Brit. Assoc. Adv. Sci.
—— **utahensis** Woodward, 1873; Geol. Mag., vol. 10, p. 523. Cambrian.
—— *vermontana*. (See **Mesonacis vermontana** Hall.)
Oryctocephalus Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 210.
—— **primus** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 210, pl. 29, figs. 3, 3 a. Middle Cambrian.
Pagura Emmons, 1860; Manual Geology, p. 280.
Dr. E. Emmons uses this term in a subgeneric sense for *Paradoxides* [*Pagura*] *quadrispinosus*. The note accompanying the Manual of Geology does not indicate the author's intentions with regard to the genus and new species. It was probably intended for *Paradoxides* [*Peltura*] *quadrispinosus*, a synonym of intended *Peltura* [*Olenus*] *kolopyga* Hall, 12th Rept. New York State Cab. Nat. Hist., p. 61. Emmons figures this species on p. 80, fig. 57.
Panderia Volborth; Mém. Acad. Sci. St.-Pétersbourg, vol. 6, p. 31.
Type, *Panderia triquetra* Volb., pl. 3, fig. 13 *bis*, 17.
—— [*Illænus*] **conradi** Billings, 1859; Canadian Naturalist, vol. 4, p. 372, figs. 7–9. Trenton.
For other references, see *Illænus conradi* Billings.
Paradoxides Brongniart, 1822; Crust. Foss., p. 30, pl. 4, fig. 1.
Type, *Paradoxides tessini* Brongniart.
Syn., *Plutonia* Salter, 1869; Quart. Jour. Geol. Soc. London, vol. 25, p. 52.
Plutonia sedgwicki, Quart. Jour. Geol. Soc. London, vol. 27, p. 399, pl. 15, figs. 1–8.
—— **acadicus** Matthew, 1882; Trans. Roy. Soc. Canada, vol. 1, p. 103, pl. 9, figs. 16–18. St. John.
—— **acadicus** Matthew, 1884; Trans. Roy. Soc. Canada, vol. 2, p. 99, pl. 1, fig. 1.
—— **acadicus** Walcott, 1884; Bull. U. S. Geol. Survey, No. 10, p. 25, pl. 6, figs. 3–3 a.
—— *arcuatus* Harlan. (See **Triarthrus beckii**.)
—— **barberi** Winchell, 1884; 13th Rept. Geol. Nat. Hist. Survey Minn., p. 65, pl. 1, fig. 7. Cambrian.
—— *beckii*. (See **Triarthrus beckii**.)
—— **bennetii** Salter, 1859; Quart. Jour. Geol. Soc. London, vol. 15, p. 553, figure. Cambrian.
—— **bennetii** Salter and Woodward, 1865; Chart of Foss. Crust., fig. 25.
—— *boltoni*. (See **Lichas boltoni**.)
—— **decorus** Billings, 1865; Pal. Foss., vol. 2, p. 75. Potsdam.
—— *eatoni*. (See **Triarthrus beckii**.)
—— **eteminicus** Matthew, 1882; Trans. Roy. Soc. Canada, vol. 1, p. 92, pl. 9, figs. 7–12. St. John.
Var. *suricoides* (figs. 4–6), var. *breviatus*, var. *malicitus* (fig. 13), var. *pontificalis* (figs. 15, 15 a), var. *quacoensis* (figs. 14, 14 a).
—— **eteminicus** Walcott, 1884; Bull. U. S. Geol. Survey, No. 10, p. 27, pl. 3, figs. 1–1 a–g.
—— **harlani** Green, 1834; Am. Jour. Sci., 1st series, vol. 35, p. 336. Cambrian.
—— **harlani** Green, 1835; Suppl. Mon. Tril. N. A., p. 14, cast 39.
—— **harlani** Rogers, 1856; Proc. Boston Soc. Nat. Hist., vol. 6, pp. 27, 40.
—— **harlani** Stodder, 1856; Proc. Boston Soc. Nat. Hist., vol. 6, p. 369.
—— **harlani** Rogers, 1856; Am. Jour. Sci., 2d series, vol. 22, p. 297.
Syn., *spinosus* Rogers, 1858; Geol. Pennsylvania, vol. 2, p. 816, fig. 590.
—— **harlani** Ordway, 1861; Proc. Boston Soc. Nat. Hist., vol. 8, p. 1, figure.
—— **harlani** Walcott, 1884; Bull. U. S. Geol. Survey, No. 10, p. 45, pl. 7, fig. 3; pl. 8, figs. 1, 1 a–c; pl. 9, fig. 1.

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Paradoxides kjerulfi (Linrs.) Matthew, 1886; Am. Jour. Sci., 3d series, vol. 31, p. 471. Cambrian.

Referred by Holm (Geol. Fören. Stockholm Förhandl., vol. 9, 1887, häfte. 7, p. 1) to *Olenellus kjerulfi* Linnarsson, pls. 14 and 15.

—— **lamellatus** Hartt, 1868; Acadian Geology, p. 656, fig. 230. St. John.

—— **lamellatus** Matthew, 1882; Trans. Royal Soc. Canada, vol. 1, p. 100, pl. 1, figs. 3, 4.

—— **lamellatus** var. **loricatus** Matthew, 1882; Trans. Royal Soc. Canada, vol. 1, p. 105, pl. 9, fig. 19.

—— **lamellatus** Walcott, 1884; Bull. U. S. Geol. Survey, No. 30, p. 25, pl. 3, figs. 2, 2 a.

—— *macrocephalus.* (See **Olenellus thompsoni** Hall.)

—— **micmac** Hartt, 1868; Acadian Geology, p. 657. St. John.

—— **micmac** Matthew, 1884; Trans. Royal Soc. Canada, vol. 2, p. 101, pl. 10, fig. 8.

—— ? *nevadensis.* (See **Olenoides nevadensis.**)

—— *quadrispinosus.* (See **Bathynotus quadrispinosus.**)

—— **tenellus** Billings, 1874; Pal. Foss., vol. 2, p. 74, fig. 43. Potsdam.

—— *thompsoni.* (See **Olenellus thompsoni** Hall.)

—— *triarthrus* Harlan; Trans. Geol. Soc. Pennsylvania, vol. 1, p. 264, pl. 15, fig. 5. (See **Triarthrus becki** Green.)

—— *vermontana.* (See **Olenellus** and **Mesonacis.**)

—— **walcotti** Shaler and Foerste, 1888; Bull. Mus. Comp. Zool. Harvard Coll., vol. 16, p. 36, pl. 2, fig. 12. Cambrian.

Peltura Milne-Edwards, 1840; Crust., vol. 3, p. 344.

—— (See **Pagura.**)

—— *holopyge.* (See **Bathynotus holopyge.**)

Pemphigaspis Hall, 1863; 16th Rept. New York State Mus. Nat. Hist., p. 221.

—— **bullata** Hall, 1863; 16th Rept. New York State Mus. Nat. Hist., p. 221, pl. 5 a, figs. 3–5. Potsdam.

A species probably of the genus *Microdiscus.*

Phacops Emmrich, 1839; De Trilobites, etc., p. 18.

Type, *Calymene latifrons* Bronn.

The generic term *Trimerocephalus* McCoy has been used by authors for species like *Phacops volborthi*, compact in form; glabella inflated and expanded in front; lobes, except the basal ones, obscure; eyes small and occupying the front portions of the head; genal angles rounded; pleura rounded; pygidium small, with few segments, and even border.

Acaste Goldfuss for such species as *Phacops downingiæ* Murch. Diagnosis: Glabella not inflated nor greatly expanded in front; furrows distinct; eyes well developed, with numerous lenses; genal angles produced into spines; pleuræ rounded or truncate; pygidium small generally, with less than eleven segments; border even, but sometimes mucronate.

—— [*Calymene*] **bufo** Green, 1832; Monthly Am. Jour. Geol., p. 559.

—— [*Calymene*] **bufo** Green, 1832; Mon. Tril. N. A., p. 41, cast 10.

—— **bufo** Hall, 1861; Des. New Species Foss., p. 65.

—— **bufo** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 93.

—— **bufo** Hall, 1876; Illus. Devonian Foss. Crust., pl. 8, figs. 24, 25.

—— **bufo** Hall, 1888; Pal. New York, vol. 7, p. 26, pl. 8, figs. 25, 26.

The fossil is said to have been found in a dark grayish limestone in the State of New Jersey. The cast approaches so near *Phacops latifrons* Bronn that it may be the same species.

—— *bombifrons.* (See **Phacops cristata.**)

—— **cacapona** Hall, 1861; Des. New Species Foss., p. 68. Hamilton.

Syn., *Calymene bufo* Castelnau, 1843; Syst. Sil. de l'Amér., p. 21, pl. 2, figs. 1–4.

—— **cacapona** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 96.

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Phacops cacapona Hall, 1876; Illus. Devonian Foss. Crust., pl. 8, figs. 18–23.
—— **cacapona** Hall. 1888; Pal. New York, vol. 7, p. 27, pl. 8, figs. 19–24.
—— *callicephala*. (See **Dalmanites callicephala.**)
—— **cristata** Hall, 1861; Des. New Species Foss., p. 67. Upper Helderberg.
Syn., *Phacops bombifrons* Hall, 1861; Des. New Species Foss., p. 67.
Phacops cristata Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 95.
Phacops cristata Hall, 1876; Illus. Devonian Foss. Crust., pl. 6, figs. 1–17.
Phacops bombifrons Hall, 1876; Illus. Devonian Foss. Crust., pl. 6, figs. 18–29.
—— **cristata** Hall, 1888; Pal. New York, vol. 7, p. 14, pl. 6, figs., 1–31, 16–29; pl. 8 a, figs. 1–4.
—— **cristata** var. **pipa** Hall, 1888; Pal. New York, vol. 7, p. 18, pl. 8 a, figs. 5–18. Upper Helderberg.
—— *downingæ* Murch. (See **Phacops trisulcatus** Hall.)
—— **hudsonica** Hall, 1859; Pal. New York, vol. 3, p. 355, pl. 73, figs. 26–28. Lower Helderberg.
—— ? *laticauda* Hall, 1847; Pal. New York, vol. 1, p. 248, pl. 64, fig. 6. (See **Dalmanites micrurus** Green.)
—— **logani** Hall, 1859; Pal. New York, vol. 3, p. 353, pl. 73, figs. 15–25. Lower Helderberg.
—— [*Calymene*] **macrophthalma** Green, 1832; Mon. Tril. N. A., p. 39, cast 9.
—— [*Calymene*] **nupera** Hall, 1843; Geol. New York, 4th Geol. Dist., p. 262, fig. 116. Chemung.
—— **nupera** Emmons, 1860; Manual Geology, p. 149, fig. 138 (2).
—— **nupera** Hall, 1876; Illus. Devonian Foss. Crust., pl. 8, fig. 26.
—— **nupera** Hall, 1888; Pal. New York, vol. 7, p. 27, pl. 8, fig. 27.
—— **orestes** Billings, 1860; Canadian Naturalist, vol. 5, p. 65, fig. 10. Middle Silurian.
—— **pulchellus** Foerste, 1887; Bull. Denison Univ., vol. 2, p. 99, pl. 8, figs. 4, 20, 21. Clinton.
—— [*Calymene bufo*] var. **rana** Green, 1832; Monthly Am. Jour. Geol., p. 559. Hamilton.
—— [*Calymene bufo*] var. **rana** Green, 1832; Mon. Tril. N. A., p. 42, casts 11, 12.
—— [*Calymene bufo*] var. **rana** Hall, 1843; Geol. New York, 4th Geol. Dist., p. 201, pl. 14.
Syn., [*Calymene*] *bufo* Owens, 1844; Geol. Expl. Iowa, Wisconsin, and Illinois, p. 74, pl. 12, fig. 1.
[*Calymene*] *bufo* Emmons, 1860; Manual Geology, p. 138, wood-cut 124, fig. 6.
—— **rana** Hall, 1861; Description New Species Fossils, p. 65.
—— **rana** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 93, pl. 10, fig. 12.
—— **rana** Meek and Worthen, 1868; Geol. Survey Illinois, vol. 3, p. 447, pl. 11, figs. 1 a–e.
—— **rana** Nicholson, 1873; Pal. Province Ontario, p. 123, figs. 5, 6 a.
—— **rana** Hall, 1876; Illus. Devonian Foss. Crust., pl. 6, figs. 14, 15; pl. 7, figs. 1–11; pl. 8, figs. 11–17.
—— **rana** Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 339, pl. 26, figs. 17–19.
—— **rana** Walcott, 1884; Pal. Eureka Dist. Mon. U. S. Geol. Survey, vol. 8, p. 207.
—— **rana** Hall, 1888; Pal. New York, vol. 7, p. 19, pl. 7, figs. 1–11; pl. 8, figs. 1–18; pl. 7 a, figs. 21–33.
—— **rana** Clarke, 1888; Jour. Morphology, vol. 2, p. 253, pl. 21.
—— **traganus** Billings, 1863; Proc. Portland Soc. Nat. Hist., vol. 1, p. 124, pl. 1, figs. 26, 27. Upper Silurian.
—— ? **trisulcatus** Hall, 1843; Geol. New York, 4th Geol. Dist., p. 72, fig. 9. Clinton.
—— **trisulcatus** Hall, 1852; Pal. New York, vol. 2, p. 300, pl. 66 a, figs. 3 a, b.

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Phæthonides Angelin, 1852; Pal. Scand., p. 21.

—— **arenicolus** Hall, 1888; Pal. New York, vol. 7, p. 134, pl. 25, figs. 12, 13.
Upper Helderberg.

—— **denticulatus** (Meek) Hall, 1888; Pal. New York, vol. 7, p. 139, pl. 25, figs. 14, 15.
For other references, see **Proetus** [*Phæton*] **denticulatus** Meek.
Steptoe Valley, Nevada, Devonian (?).

—— **gemmæus** Hall, 1888; Pal. New York, vol. 7, p. 136, pl. 24, figs. 32–36.
Upper Helderberg.

—— **immaturus** Herrick, 1889; Bull. Denison Univ., vol. 4, p. 59, pl. 1, figs. 9-15.
Kinderhook.

—— (?) **lodiensis** (Meek) Herrick, 1889; Bull. Denison Univ., vol. 4, p. 59.
For other references, see **Brachymetopus lodiensis** Meek.

—— **occidentalis** Herrick, 1889; Bull. Denison Univ., vol. 4, p. 57, pl. 1, figs. 10 a, b.
Kinderhook.

—— **sedaliensis** (Vogdes) Herrick, 1889; Bull. Denison Univ., vol. 4, p. 57.
Waverly.
For other references, see **Griffithides ? sedaliensis** Vogdes.

—— **spinosus** Herrick, 1889; Bull. Denison Univ., vol. 4, p. 58, pl. 1, figs. 4–5.
Kinderhook.

—— **varicella** Hall, 1888; Pal. New York, vol. 7, p. 135, pl. 24, figs. 29–31.
Upper Helderberg.

Phillipsia Portlock, 1843; Rept. Geol. Londonderry, etc., p. 315.
Type, *Phillipsia gemmulifera* Phillips.

Dr. Henry Woodward suggests (Geol. Mag., vol. 10, 1883) the following brief diagnosis of the characters of the genera *Phillipsia* and *Griffithides*, which may be found useful in separating the genera:

	Phillipsia.	Griffithides.
1	Sides of the glabella nearly parallel.....	Glabella pyriform.
2	Marked by either two or three short lateral furrows.	No short lateral furrows on the glabella.
3	Basal lobes continuous with the glabella..	Basal lobes distinct from the glabella.
4	Eyes large, reniform.....	Eyes small, suboval.

—— *bufo*. (See **Griffithides bufo**.)

—— **cliftonensis** Shumard, 1858; Trans. Acad. Nat. Sci. St. Louis, vol. 1, p. 227.
Coal Measures.

—— **cliftonensis** Herrick, 1887; Bull. Denison Univ., vol. 2, p. 11.

—— **cliftonensis** Vogdes, 1887; Annals New York Acad. Sci., vol. 4, p. 84.

—— ? **consors** Herrick, 1889; Bull. Denison Univ., vol. 4, p. 53, pl. 1, figs. 16 a, b, c.
Keokuk or Burlington.

—— **consors** Herrick, 1890; American Geologist, vol. 5, p. 254.

—— ? *coronata*. (See **Cyphaspis coronata** Hall.)

—— *doris* (Hall) Winchell, 1865; Proc. Acad. Nat. Sci. Phila., 2d series, vol. 9, p. 133. (See **Proteus doris** Hall.)

—— **howi** Billings, 1863; Canadian Naturalist, vol. 8, p. 209, figure. Carboniferous.

—— **howi** Dawson, 1868; Acadian Geology, p. 313, fig. 133.

—— **howi** Herrick, 1887; Bull. Denison Univ., vol. 2, p. 63.

—— **howi** Vogdes, 1887; Annals New York Acad. Sci., vol. 4, p. 91.
Compare *Phillipsia meramecensis*.

—— **insignis** Winchell, 1863; Proc. Acad. Nat. Sci. Phila., 2d series, vol. 7, p. 24.
Burlington.

—— **insignis** Billings, 1863; Canadian Naturalist, vol. 8, p. 209.

—— **insignis** Herrick, 1887; Bull. Denison Univ., vol. 2, p. 63.

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Phillipsia insignis Vogdes, 1887; Annals New York Acad. Sci., vol. 4, p. 87.
—— *lævis*. (See **Cyphaspis lævis**.)
—— **major** Shumard, 1858; Trans. Acad. Sci. St. Louis, vol. 1, p. 226. Coal Measures.
—— **major** Meek, 1872; U. S. Geol. Survey Territories, Final Rept. Nebraska, p. 238, pl. 3, figs. 2 a, b, c.
—— **major** Herrick, 1887; Bull. Denison Univ., vol. 2, p. 60.
—— **major** Vogdes, 1887; Annals New York Acad. Sci., vol. 4, p. 85, pl. 3, fig. 14.
—— **meramecansis** Shumard, 1855; 1st and 2d Rept. Geol. Survey Missouri, p. 199, pl. B, fig. 9. Archimides Limestone.
—— **meramecansis** Herrick, 1887; Bull. Denison Univ., vol. 2, p. 59.
—— **meramecansis** Vogdes, 1887; Annals New York Acad. Sci., vol. 4, p. 86, pl. 3, fig. 15.
Syn., *meramecansis?* Winchell, 1863; Proc. Acad. Nat. Sci. Phila., 2d series, vol. 7, p. 24. Keokuk.
—— **meramecansis** Herrick, 1888; Bull. Denison Univ., vol. 3, p. 28, pl. 11, fig. 3.
Syn., *howi* (Billings) Vogdes, 1887; Annals New York Acad. Sci., vol. 4, p. 92.
vindobonensis (Hartt) Vogdes, 1887; Annals New York Acad. Sci., vol. 4, p. 92.
—— **meramecansis** Herrick, 1889; Bull. Denison Univ., vol. 4, p. 54, pl. 1, fig. 6.
—— *minuscula* Hall. (See **Cyphaspis minuscula**.)
—— **missouriensis** Shumard, 1858; Trans. Acad. Sci. St. Louis, vol. 1, p. 220. Coal Measures.
—— **missouriensis** Herrick, 1887; Bull. Denison Univ., vol. 2, p. 59.
—— **missouriensis** Vogdes, 1887; Annals New York Acad. Sci., vol. 4, p. 86, pl. 3, figs. 1, 2, 14, 16.
—— *? ornatus*. (See **Cyphaspis coronata**.)
—— [*Griffithides*] *portlocki* Meek and Worthen. (See **Griffithides portlocki**.)
—— **perannulata** Shumard, 1858; Trans. Acad. Sci. St. Louis, vol. 1, p. 296, pl. 11, fig. 10. Permian.
—— **perannulata** Vogdes, 1887; Annals New York Acad. Sci., vol. 4, p. 84.
—— **præcursor** Herrick, 1888; Bull. Denison Univ., vol. 3, p. 29, pl. 12, fig. 1. Kinderhook.
—— **præcursor** Herrick, 1890; American Geologist, vol. 5, p. 254.
—— [*Proetus*] **præcursor** Herrick, 1889; Bull. Denison Univ., vol. 4, p. 54, pl. 1, fig. 1. Waverly.
—— **rockfordensis** Winchell, 1865; Proc. Acad. Nat. Sci. Phila., 2d series, vol. 9, p. 133. Kinderhook.
—— **rockfordensis** Herrick, 1887; Bull. Denison Univ., vol. 2, p. 62.
—— **rockfordensis** Vogdes, 1887; Annals New York Acad. Sci., vol. 4, p. 91.
—— **sampsoni** Vogdes, 1888; Trans. New York Acad. Sci., vol. 7, p. 248, figure. Waverly.
—— [*Griffithides*] *sangamonensis* Meek and Worthen. (See **Griffithides sangamonensis**.)
—— [*Griffithides*] *scitula* Meek and Worthen. (See **Griffithides scitula**.)
—— **serraticaudata** Herrick, 1889; Bull. Denison Univ., vol. 4, p. 52, pl. 1, figs. 8 a–d. Keokuk.
—— **serraticaudata** Herrick, 1890; American Geologist, vol. 5, p. 254.
—— *shumardi*. (See **Proetus auriculata**.)
—— **stevensoni** Meek, 1871; Rept. Regents Univ. West Virginia, p. 73. Chester.
—— **stevensoni** Vogdes, 1887; Annals New York Acad. Sci., vol. 4, p. 88, pl. 3, fig. 6.
—— **tuberculata** Meek and Worthen, 1870; Proc. Acad. Nat. Sci. Phila., p. 52. Burlington.
—— **tuberculata** Vogdes, 1887; Annals New York Acad. Sci., vol. 4, p. 92.
—— **trinucleata** Herrick, 1887; Bull. Denison Univ., vol. 2, p. 64, pl. 1, figs. 23, 23 a, c, e, h; pl. 2, fig. 32; pl. 3, fig. 21. Coal Measures.

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Phillipsia trinucleata Herrick, 1889; Bull. Denison Univ., vol. 4, p. 49.
Syn., *Proetus trinucleatus* Vogdes, 1888; Annals New York Acad. Sci., vol. 4, p. 8 (in error), pl. 2, figs. 7, 8, 9.
vindobonensis Hartt, 1868; Acadian Geology, p. 353. Carboniferous.
vindobonensis Herrick, 1887; Bull. Denison Univ., vol. 2, p. 63.
—— *vindobonensis* Vogdes, 1887; Annals New York Acad. Sci., vol. 4, p. 89. (See **Phillipsia meramecensis** Shumard.)
Piliolites Cozzens, 1846; Annals Lyceum Nat. Hist. New York, vol. 4, p. 157.
—— *ohioensis* Cozzens, 1846; Annals Lyceum Nat. Hist. New York, vol. 4, p. 157, pl. 16, figs. 1 a, 1 b. (See **Proetus crassimarginatus ?**)
Proetus Steininger, 1831; Mém. Soc. Géol. France, vol. 1, p. 355, pl. 24, fig. 6.
Type, *Proetus cuvieri* Steininger.
Syn., *Æonia* Burmeister, 1843; Organization Trilobites, p. 116 (Ray Soc. ed., p. 100). Burmeister separates Dalman's species *Calymene concinna* from the type of the genus *Proetus*, and gives a generic description of *Æonia*, with descriptions and figures of *A. concinna*, *A. stokesii*, and *A. verticalis*.
Phæton Barrande, 1846; Notice Prélim., p. 62. The author herein gives the new generic term *Phæton* for species of *Proetus* with fimbriated pygidia.
Prinopeltis Corda, 1847; Prodr., p. 121. New generic name proposed for the preoccupied term of *Phæton*.
Xiphogonium Corda, 1847; Prodr., p. 70. Proposed genus for certain species of *Proetus*, with nine segments in the thorax.
Goniopleura Corda, 1847; Prodr., p. 80. This genus includes such species as *Proetus elegantulus* Loven, with twelve segments in the thorax.
Forbesia McCoy, 1847; Sil. Foss. Ireland, p. 46. This author uses for the types of his genus *Forbesia latifrons* and *F. stokesii*, which is the same as that used by Barrande in 1846 for his genus *Phæton* and *Angelin* in 1878 for the genus *Phæthonides*.
Gerastos Goldfuss, 1843; Neues Jahrbuch für Mineral., p. 557. This genus is a *Proetus* with *G. lævigatus* for its type, a species identical with *Proetus cuvieri* Stein.
Trigonaspis and *Cylindraspis* the Brothers Sanderberger; Verst. d. Rhein, Scht.-Syst., p. 30, pl. 3, 1850.
Deckenella Kayser, 1880; Zeitschr. Deutsch. geol. Gesell., Berlin, 1880, p. 703. For such species as *Proetus verticallis* and *P. haldemani*.
—— **alaricus** Billings, 1860; Canadian Naturalist, vol. 5, p. 68, fig. 12. Hudson.
—— **alaricus** Billings, 1863; Geol. Canada, p. 219, fig. 230.
—— **angustifrons** Hall, 1861; Des. New Species Foss., p. 70. Schoharie.
—— **angustifrons** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 98.
—— **angustifrons** Hall, 1876; Illus. Devonian Foss. Crust., pl. 20, figs. 1, 4, 7.
—— **angustifrons** Hall, 1888; Pal. New York, vol. 7, p. 91, pl. 20, figs. 1–5; pl. 22, figs. 1–3.
—— *auriculatis*. (See **Proetus missouriensis** Shumard.)
—— **canaliculatus** Hall, 1861; Des. New Species Foss., p. 73. Upper Helderberg.
—— **canaliculatus** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 101.
—— **canaliculatus** Hall, 1876; Illus. Devonian Foss. Crust., pl. 20, figs. 10, 11.
—— **canaliculatus** Hall, 1888; Pal. New York, vol. 7, p. 107, pl. 20, figs. 10, 11; pl. 23, figs. 10, 11.
—— **clarus** Hall, 1861; Des. New Species Foss., p. 71. Upper Helderberg.
—— **clarus** Hall, 1862; 15th Rept. New York State Mus. Nat. Hist., p. 99.
—— **clarus** Hall, 1876; Illus. Devonian Foss. Crust., pl. 20, figs. 12–14.
—— **clarus** Hall, 1888; Pal. New York, vol. 7, p. 104, pl. 20, figs. 12–14; pl. 22, figs. 28–30.
—— **conradi** Hall, 1861; Des. New Species Foss., p. 69. Schoharie.

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Proetus conradi Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 97.
—— **conradi** Hall, 1876; Illus. Devonian Foss. Crust., pl. 21, fig. 6 (not figs. 5, 8, 9); pl. 21, figs. 27, 28.
Syn., *Conradi* Hall, 1876; Illus. Devonian Foss. Crust., pl. 20, figs. 5, 8, 9.
Piliolites ohionensis? Cozzens, 1846; Annals Lyceum Nat. Hist. New York, vol. 7, p. 99, pl. 10, figs. 1 a, b.
—— **conradi** Hall and Clarke, 1888; Pal. New York, vol. 7, p. 89, pl. 20, fig. 9; pl. 21, figs. 27, 28; pl. 12, fig. 4.
—— [*Asaphus*] **corycœus** Conrad, 1842; Jour. Acad. Nat. Sci. Phila., vol. 8, p. 277, pl. 16, fig. 15. Niagara.
—— [*Asaphus*] **corycœus** Hall, 1843; Geol. New York, 4th Geol Dist, pl. 19, fig. 3.
—— **corycœus** Hall, 1852; Pal. New York, vol. 2, p. 315, pl. 67, fig. 15.
—— [*Calymene*] **crassimarginatus** Hall, 1843; Geol. New York, 4th Geol. Dist., p. 172, fig. 5. Upper Helderberg.
—— **crassimarginatus** Hall, 1859; 12th Rept. New York State Cab. Nat. Hist., p. 88.
—— [*Phillipsia*] **crassimarginatus** Billings, 1861; Canadian Journal, vol. vi, p. 362.
—— **crassimarginatus** Hall, 1861; Des. New Species Foss., p. 72.
—— **crassimarginatus** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 100, pl. 10, fig. 10.
—— **crassimarginatus** Hall, 1876; Illus. Devonian Foss. Crust., pl. 20, figs. 20–31.
—— **crassimarginatus** Hall, 1888; Pal. New York, vol. 7, p. 99, pl. 20, figs. 6–8, 20–31; pl. 22, figs. 20–62; pl. 25, fig. 8.
—— **curvimarginatus** Hall, 1888; Pal. New York, vol. 7, p. 94, pl. 22, figs. 13–19. Schoharie.
—— *davenportensis* Barris. (See **Proetus prouti** Shumard.)
—— **dephinulus** Hall, 1888; Pal. New York, vol. 7, p. 111, pl. 23, figs. 1, 2; pl. 25, fig. 6. Upper Helderberg.
—— **denticulatus** Meek, 1877; U. S. Geol. Expl. 40th Par., vol. 4, p. 49, pl. 1, figs. 10 a, b. Devonian.
—— **determinatus** Foerste, 1887; Bull. Denison Univ., vol. 2, p. 91, pl. 8, figs. 2, 3, 3 a. Clinton.
—— **doris** Hall, 1860; 13th Rept. New York State Cab. Nat. Hist., p. 112. Goniatite limestone.
—— [*Phillipsia*] **doris** Winchell, 1865; Proc. Acad. Nat. Sci. Phila., 2d series, vol. 2, p. 62.
—— [*Phillipsia*] **doris** Herrick, 1887; Bull. Denison Univ., vol. 2, p. 62.
—— [*Phillipsia*] **doris** Vogdes, 1887; Annals New York Acad. Sci., vol. 4, p. 90 (in error).
—— **ellipticus** Meek and Worthen, 1865; Proc. Acad. Nat. Sci. Phila., p. 267. Kinderhook.
—— **ellipticus** Meek and Worthen, 1868; Geol. Survey Illinois, vol. 3, p. 460, pl. 14, fig. 3.
—— **ellipticus** Vogdes, 1887; Annals New York Acad. Sci., vol. 4, p. 82, pl. 3, fig. 3.
—— **follicepS** Hall, 1888; Pal. New York, vol. 7, p. 101, pl. 23, figs. 3–8. Upper Helderberg.
—— *granulatus* Wetherby. (See **Griffithides granulatus**.)
—— **haldemani** Hall, 1861; Des. New Species Foss., p. 74. Hamilton.
—— **haldemani** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 102, pl. 10, fig. 6.
—— **haldemani** Hall, 1876; Illus. Devonian Foss. Crust., pl. 21, figs. 7–9.
—— **haldemani** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 210.
—— **haldemani** Herrick, 1889; Bull. Denison Univ., vol. 4, p. 55, pl. 1, fig. 12.
—— **haldemani** Hall, 1888; Pal. New York, vol. 7, p. 113, pl. 21, figs. 7–9; pl. 23, figs. 13–15.

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Proetus [*Dechenella*] **haldemani** Kayser, 1880; Zeitschr. Deutsch. geol. Gesell., Berlin, 1880, p. 770, pl. 27, fig. 9.

—— [*Dechenella*] **haldemani** Tschernyschew, 1887; Mém. Comité Géol., vol. 3, No. 3, p. 14, pl. 1, fig. 9.

—— **hesione** Hall, 1861; Des. New Species Foss., p. 70. Schoharie.

—— **hesione** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 98.

—— **hesione** Hall, 1876; Illus. Devonian Foss. Crust., pl. 20, figs. 15, 16.

—— **hesione** Hall, 1888; Pal. New York, vol. 7, p. 93, pl. 20, figs. 15, 16.

—— **jejunus** Hall, 1888; Pal. New York, vol. 7, p. 124, pl. 25, fig. 7. Hamilton.

—— **junius** Billings, 1863; Proc. Portland Soc. Nat. Hist., vol. 1, p. 122, pl. 1, fig. 23. Upper Silurian.

—— **latimarginatus** Hall, 1888; Pal. New York, vol. 7, p. 97, pl. 22, figs. 7–12. Schoharie.

—— **loganensis** Hall and Whitfield, 1877; U. S. Geol. Expl., 40th Par., vol. 4, p. 264, pl. 4, fig. 33. Waverly.

—— **loganensis** Vogdes, 1887; Annals New York Acad. Sci., vol. 4, p. 78.

—— **longicaudus** Hall, 1861; Des. New Species Foss., p. 80. Hamilton.

—— **longicaudus** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 108, pl. 10, figs. 7–9.

—— **longicaudus** Hall, 1876; Illus. Devonian Foss. Crust., pl. 20, figs. 32–34.

—— **longicaudus** Williams, 1881; Am. Jour Sci., 3d series, vol. 21, p. 156.

—— (?) **longicaudus** Hall, 1888; Pal. New York, vol. 7, p. 131, pl. 20. figs. 32–34.

—— **macrobius** Billings, 1863; Proc. Portland Soc. Nat. Hist., vol. 1, p. 123, pl. 1, fig. 24. Upper Silurian.

—— **macrocephalus** Hall, 1861; Des. New Species Foss., pp. 77, 79. Hamilton.

—— **macrocephalus** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., pp. 105, 107.

—— **macrocephalus** Hall, 1876; Illus. Devonian Foss. Crust., pl. 21, figs. 10–21.

—— **macrocephalus** Hall, 1888; Pal. New York, vol. 7, p. 116, pl. 21, figs. 10–21; pl. 23, fig. 30.

—— [*Calymene*] **marginalis** Conrad, 1839; Ann. Rept. Pal. Dept. New York Geol. Survey, p. 66. Tully Limestone.

—— **marginalis** Hall, 1861; Des. New Species Foss., p. 76. Hamilton.

—— **marginalis** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 104.

—— **marginalis** Hall, 1876; Illus. Devonian Foss. Crust., pl. 21, figs. 24–28.

—— **marginalis** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 210.

—— **marginalis** Hall, 1888; Pal. New York, vol. 7, p. 122.

—— **microgemma** Hall, 1888; Pal. New York, vol. 7, p. 109, pl. 22, figs. 33, 34. Upper Helderberg.

—— **minuscula** Hall, 1876; Illus. Devonian Foss. Crust., pl. 20, fig. 17.

—— **minutus** Herrick, 1889; Bull. Denison Univ., vol. 4, p. 56, pl. 1, figs. 7 a, b. Kinderhook.

—— **minutus** Herrick, 1890; American Geologist, vol. 5, p. 254.

—— **missouriensis** Shumard, 1855; 1st and 2d Rept. Geol. Missouri, p. 196, pl. B, figs. 13 a, b. Waverly.

Syn., *auriculatus* Hall, 1861; Des. New Species Foss., p. 79.

auriculatus Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 107.

[*Phillipsia* (*Proetus*)] *auriculatus* Herrick, 1889; Bull. Denison Univ., vol. 4, p. 34, pl. 1, fig. 14.

[*Phillipsia*] *shumardi* Herrick, 1887; Bull. Denison Univ., vol. 2, pp. 58, 69, pl. 7, fig. 14.

—— **missouriensis** Vogdes, 1887; Annals New York Acad. Sci., vol. 4, p. 75, pl. 3, fig. 1.

—— **missouriensis** Hall, 1888; Pal. New York, vol. 7, p. 133, pl. 23, fig. 32.

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Proetus occidens Hall, 1861; Des. New Species Foss., p. 80. Hamilton.
—— **occidens** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 108.
—— **occidens** Hall, 1876; Illus. Devonian Foss. Crust., pl. 21, figs. 22, 23.
—— **occidens** Hall, 1888; Pal. New York, vol. 7, p. 130, pl. 21, figs. 22, 23.
—— **ovifrons** Hall, 1888; Pal. New York, vol. 7, p. 110, pl. 22, figs. 31, 32. Upper Helderberg.
—— **pachydermatus** Barrett, 1873; Am. Jour. Sci., 3d series, vol. 15, p. 370. Niagara.
—— **parvisculus** Hall, 1872; 24th Rept. New York State Cab. Nat. Hist., p. 223, pl. 8, fig. 14. Hudson.
—— **parvisculus** Hall and Whitfield, 1875; Pal. Ohio, vol. 2, p. 109, pl. 4, fig. 18.
—— **parvisculus** Miller, 1874; Cincinnati Quart. Jour. Sci., vol. 1, p. 144.
—— **peroccidens** Hall and Whitfield, 1877; U. S. Geol. Expl. 40th Par., Pal., vol. 4, p. 262, pl. 4, figs. 28–32. Waverly.
—— **peroccidens** Vogdes, 1887; Annals New York Acad. Sci., vol. 4, p. 79.
—— **phocion** Billings, 1874; Pal. Foss., vol. 2, p. 63, fig. 31. Devonian.
—— **phocion** Hall, 1888; Pal. New York, vol. 7, p. 125, pl. 25, figs. 9, 10.
—— **planimarginatus** Meek, 1871; Proc. Acad. Nat. Sci. Phila., p. 89. Corniferous.
—— **planimarginatus** Meek, 1873; Pal. Ohio, vol. 1, p. 233, pl. 23, figs. 3 a, b.
—— **planimarginatus** Hall, 1888; Pal. New York, vol. 7, p. 112, pl. 23, fig. 12.
—— **protuberans** Hall, 1859; Pal. New York, vol. 3, p. 351, pl. 73, figs. 5–8. Lower Helderberg.
—— **prouti** Shumard, 1863; Trans. Acad. Sci. St. Louis, vol. 2, p. 110. Hamilton.
Syn., *davenportensis* Barris, 1878; Proc. Davenport Acad. Sci., vol. 2, p. 287, pl. 11, fig. 8 (pl. 11, fig. 8, revised).
—— **prouti** Hall, 1888; Pal. New York, vol. 7, p. 126, pl. 23, figs. 16–18.
—— [*Calymene*] **rowi** Le Row, 1837; Poughkeepsie Telegram, Nov. 22. Hamilton.
—— [*Calymene*] **rowi** Green, 1838; Am. Jour. Sci., 1st series, vol. 33, p. 406.
—— [*Calymene*] **rowi** Green, 1838; Annals Mag. Nat. Hist., 1st series, London, vol. 1, p. 79.
—— **rowi** Hall, 1861; Des. New Species Foss., p. 75.
—— **rowi** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 103.
—— **rowi** Hall, 1876; Illus. Devonian Foss. Crust., pl. 21, figs. 2–6.
—— **rowi** Hall, 1888; Pal. New York, vol. 7, p. 119, pl. 21, figs. 2–6, 24–26; pl. 23, figs. 20–29.
—— [*Phillipsia*] **shumardi** Herrick, 1887; Bull. Denison Univ., vol. 2, pp. 58, 69, pl. 7, figs. 14 a, b. Waverly.
—— [*Phillipsia*] **shumardi** Herrick, 1888; Bull. Denison Univ., vol. 3, p. 29.
—— **spurlocki** Meek, 1872; Am. Jour. Sci., 3d series, vol. 3, p. 426. Hamilton.
—— **spurlocki** Meek, 1873; Pal. Ohio, vol. 1, p. 161, pl. 14, fig. 12.
—— **spurlocki** Miller, 1874; Cincinnati Quart. Jour. Sci., vol. 1, p. 145.
—— **stenopyge** Hall, 1888; Pal. New York, vol. 7, p. 110, pl. 22, fig. 27. Upper Helderberg.
—— **stokesi** (Murch.) Hall, 1852; Pal. New York, vol. 2, p. 316, pl. 67, figs. 13, 14. Niagara.
—— **swallowi** Shumard, 1855; 1st and 2d Rept. Geol. Survey Missouri, p. 196, pl. B, figs. 12 a, b. Waverly.
—— [*Phillipsia*] **swallowi** Herrick, 1887; Bull. Denison Univ., vol. 2, p. 58.
—— [*Phillipsia*] **tennesseensis** Winchell, 1869; Geol. Tennessee, p. 445. Waverly.
—— **tennesseensis** Vogdes, 1887; Annals New York Acad. Sci., vol. 4, p. 80.
—— **tumidus** Hall, 1888; Pal. New York, vol. 7, p. 113, pl. 23, fig. 9. Upper Helderberg.
—— **verneuilli** Hall, 1861; Des. New Species Foss., p. 73. Upper Helderberg.
—— **verneuilli** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 101.
—— **verneuilli** Hall, 1876; Illus. Devonian Foss. Crust., p. 20, figs. 18, 19.

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Proetus verneuilli Hall, 1888; Pal. New York, vol. 7, p. 108, pl. 20, figs. 18, 19.
Protichnites Owen, 1852; Quart. Jour. Geol. Soc. London, vol. 8, p. 214.
— **alternans** Owen, 1852; Quart. Jour. Geol. Soc. London, vol. 8, p. 221, pl. 8 a, fig. 7. Potsdam.
— **carbonarius** Dawson, 1873; Am. Jour. Sci., 3d series, vol. 5. Coal Measures.
— **latus** Owen, 1852; Quart. Jour. Geol. Soc. London, vol. 8, p. 218, pl. 11. Potsdam.
— **lineatus** Owen, 1852; Quart. Jour. Geol. Soc. London, vol. 8, p. 220, pl. 8 a, pl. 13. Potsdam.
— **logananus** Marsh, 1869; Am. Jour. Sci., 2d series, vol. 48, p. 46. Potsdam.
— **multinotatus** Owen, 1852; Quart. Jour. Geol. Soc. London, vol. 8, p. 219, pl. 12. Potsdam.
— **octo-notatus** Owen, 1852; Quart. Jour. Geol. Soc. London, vol. 8, p. 217, pl. 10. Potsdam.
— **septem-notatus** Owen, 1852; Quart. Jour. Geol. Soc. London, vol. 8, p. 214, pl. 9. Potsdam.
Protypus Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 211.
— [*Angelina*] **hitchcocki** Whitfield, 1884; Bull. Am. Mus. Nat. Hist., New York, vol. 1, p. 148, pl. 14, fig. 13. Potsdam.
— **hitchcocki** Walcott 1886; Bull. U. S. Geol. Survey, No. 30, p. 211, pl. 31, fig. 4.
— [*Bathyurus*] **senectus** Billings, 1861; Geol. Vermont, vol. 2, p. 953, figs. 359, 360. Middle Cambrian.
— [*Bathyurus*] **senectus** Billings, 1861; Pamphlet published in adv. Pal. Foss. Canada, p. 15, figs. 20, 21.
— [*Bathyurus*] **senectus** Billings, 1863; Geol. Canada, p. 286, figs. 298 a, b.
— [*Bathyurus*] **senectus** Billings, 1865; Pal. Foss., vol. 1, p. 15, figs. 20, 21.
— **senectus** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 213, pl. 31, figs. 2, 2 a–c.
Pterocephalia Roemer, 1852; Kreid. von Texas, p. 93.
— [*Conocephalites* (*Pterocephalia*)] **laticeps** Hall and Whitfield, 1877; U. S. Geol. Expl. 40th Par., vol. 4, p. 221, pl. 2, figs. 4–7. Potsdam.
— [*Ptychoparia* (*Pterocephalia*)] **laticeps** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 69.
— [*Ptychoparia* (*Pterocephalia*)] **occidens** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 58, pl. 9, fig. 21. Cambrian.
— **sancti-sabæ** Roemer, 1849; Texas, p. 421. Potsdam.
— **sancti-sabæ** Roemer, 1852; Kreid. von Texas, p. 93, pl. 11.
Ptychaspis Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 170.
Type, *Ptychaspis miniscaensis* Hall.
— **barabuensis** Winchell, 1864; Am. Jour. Sci., 2d series, vol. 37, p. 230. Potsdam.
— [*Arionellus*] **cylindricus** Billings, 1865; Pal. Foss., vol. 1, p. 406, fig. 385.
— [*Conoceph.* (*Ptychaspis?*)] **explanatus** Whitfield, 1880; Ann. Rept. Geol. Survey. Wisconsin, 1879, p. 48. Potsdam.
— [*Conoceph.* (*Ptychaspis?*)] **explanatus** Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 181, pl. 1, figs. 27, 28.
Syn., *granulosa* Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 173, pl. 6, figs. 33–4).
granulosa Whitfield, 1878; Ann. Rept. Geol. Survey Wisconsin, 1877, p. 34.
granulosa Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 185, pl. 1, fig. 24.
In this work *Ptychaspis granulosa* Hall (not Owen) is referred to *Ptychaspis striata*.
— **granulosa** Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 185, pl. 1, fig. 24.
Syn., *Dikelocephalus miniscaensis* Owen, 1852; Rept. Geol. Survey Wisconsin, Iowa, and Minnesota, p. 574, pl. 1, figs. 3, 12; pl. 1 a, figs. 4, 5.
— [*Dikelocephalus*] **granulosus** Owen, 1852; Rept. Geol. Survey Wisconsin, Iowa, and Minnesota, p. 575, pl. 1, fig. 7. Potsdam.

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Ptychaspis miniscaensis Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 171, pl. 6, figs. 41–46; pl. 10, figs. 21, 22.

—— **minuta** Whitfield, 1878; Ann. Rept. Geol. Survey Wisconsin, 1877, p. 55. Potsdam.

—— **minuta** Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 186, pl. 1, figs. 25, 26.

—— **minuta** Walcott, 1884; Pal. Eureka Dist., Mon. U. Geol. Survey, vol. 8, p. 60, pl. 10, fig. 23.

—— **pustulosa** Hall and Whitfield, 1877; U. S. Geol. Expl. 40th Par., Palæont., vol. 4, p. 223, pl. 2, fig. 27. Potsdam.

—— [*Dikelocephalus*] **sesostris** Billings, 1865; Pal. Foss., vol. 1, p. 198, fig. 184. Quebec.

—— **speciosus** Walcott, 1879; 32d Rept. New York State Mus. Nat. Hist., p. 131. Calciferous.

—— **striata** Whitfield, 1878; Ann. Rept. Geol. Survey Wisconsin, 1877, p. 55. Potsdam.

—— **striata** Whitfield, 1880; Ann. Rept. Geol. Survey Wisconsin, 1879, p. 51.

—— **striata** Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 186.

Syn., *granulosa* Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 173, pl. 6, figs. 33–40.

—— [*Arionellus*] **subolavatus** Billings, 1860; Canadian Naturalist, vol. 5, p. 315, figs. 15, 15 a. Quebec.

Ptychoparia Corda, 1847; Prodr., p. 141, pl. 2, fig. 11.

Type, *Ptychoparia striatus* Emmrich.

—— [*Conocephalites*] **adamsi** Billings, 1861; Pamphlet published in adv. Pal. Foss., p. 12, figure.

—— [*Conocephalus*] Adams, 1848; Am. Jour. Sci., 2d series, vol. 5, p. 109.

—— [*Conocephalites*] **adamsi** Billings, 1861; Geol. Vermont, vol. 2, p. 950, fig. 355.

—— [*Conocephalus*] Billings, 1861; Am. Jour Sci., 2d series, vol. 32, p. 231.

—— [*Conocephalus*] Billings, 1861; Canadian Naturalist, vol. 6, p. 324.

—— [*Conocephalites*] **adamsi** Billings, 1863; Geol. Canada, p. 286, fig. 294.

—— [*Conocephalites*] **adamsi** Billings, 1865; Pal. Foss., vol. 1, p. 12, fig. 15.

—— **adamsi** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 195, pl. 26, figs. 1, 1 a–c. Middle Cambrian.

Syn., *arenosus* (Billings) Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 195.

—— [*Euloma?*] **affinis** Walcott, 1882; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 54, pl. 10, fig. 12. Cambrian and Silurian.

—— [*Crepicephalus* (*Bathyurus*)] **angulatus** Hall and Whitfield, 1877; U. S. Geol. Expl. 40th Par., Palæont., vol. 4, p. 220, pl. 2, fig. 28. Potsdam.

—— ? **angulatus** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 269.

—— ? **annectans** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 91, pl. 12, fig. 18. Cambrian.

—— [*Crepicephalus* (*Loganellus*)] **anytus** Hall and Whitfield, 1877; U. S. Geol. Expl. 40th Par. vol. 4, p. 219, pl. 2, figs. 19–21. Potsdam.

—— **anytus** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 56, pl. 9, fig. 26.

—— [*Lisostracus*] **anytus** Brögger, 1886; Geol. Fören. Stock. Förhandl., vol. 8, p. 212.

—— [*Conoceph.*] **antiquatus** Salter, 1859; Quart. Jour. Geol. Soc. London, vol. 15, p. 554, fig. 2. Potsdam.

Syn., [*Conoceph.*] *arenosus* Billings, 1861; Geol. Vermont, vol. 2, p. 952, fig. 358.

[*Conoceph.*] *arenosus* Billings, 1861; Pamphlet published in advance of Pal. Foss. Canada, vol. 1; also, Pal. Foss., vol. 1, p. 15, fig. 18.

[*Conoceph.*] *arenosus* Billings, 1863; Geol. Canada, p. 286, fig. 297.

Walcott (Bull. U. S. Geol. Survey, No. 30, p. 195) refers this species to *Ptychoparia adamsi*.

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Ptychoparia [*Conoceph.*] *aurora* Hartt, 1868; Acadian Geology, p. 653. (See **Ptychoparia ouangondianus.**)

—— [*Conoceph.*] **billingsi** Shumard, 1861; Am. Jour. Sci., 2d series, vol. 32, p. 219. Potsdam.

—— [*Conoceph.?*] **binodosus** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 160, pl. 7, fig. 47. Potsdam.

—— [*Solenopleura?*] **breviceps** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 49, pl. 10, fig. 9. Cambrian.

—— [*Conocephalites*] **calymenoides** Whitfield, 1878; Ann. Rept. Geol. Survey Wisconsin, 1877, p. 52. Potsdam.

—— [*Conocephalites*] **calymenoides** Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 179, pl. 3, figs. 2–5.

—— **calymenoides** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 48.

—— [*Crepicephalus* (*Loganellus*)] **centralis** Whitfield, 1880; Geol. Resources Black Hills Dakota, p. 341, pl. 2, figs. 21–24. Potsdam.

—— [*Conocephalites*] **chippewaensis** (Owen) Shumard, 1863; Trans. St. Louis Acad. Sci., vol. 2, p. 104.

—— [*Lonchocephalus*] **chippewaensis** Owen, 1852; Rept. Geol. Survey Wisconsin, Iowa, and Minnesota, p. 576, pl. 8, figs. 6, 14; pl. 1 a, fig. 9.

—— ? (subgenus?) **clavata** Walcott, 1887; Am. Jour. Sci., 3d series, vol. 34, p. 198, pl. 1, fig. 3. Cambrian.

—— [*Conoceph*] **cordilleræ** Rominger, 1887; Proc. Acad. Nat. Sci. Phila., p. 17, pl. 1, fig. 7. Cambrian.

—— **cordilleræ** Walcott, 1888; Am. Jour. Sci., 3d series, vol. 36, p. 165.

—— [*Conoceph*] **depressus** Shumard, 1861; Am. Jour. Sci., 2d series, vol. 32, p. 219. Potsdam.

—— [*Conoceph*] **diadematus** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 167, pl. 7, figs. 36–39; pl. 9, figs. 18–21 (?). Potsdam.

—— [*Euloma?*] **dissimilis** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 51, pl. 9, fig. 28. Cambrian.

—— [*Conoceph* (*Arionellus?*)] **dorsalis** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 222. Potsdam.

—— [*Conoceph*] **elegans** Hartt, 1868; Acadian Geology, p. 650. St. John.

—— [*Conoceph*] **eos** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 151, pl. 7, figs. 24, 25; pl. 8, figs. 2–9. Potsdam.

—— **eos** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 51.

—— [*Conoceph.*] **eryon** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 157, pl. 7, figs. 10–16; pl. 8, figs. 16, 31. Potsdam.

—— **fitchi** Walcott, 1887; Am. Jour. Sci., 3d series, vol. 34, p. 197, pl. 1, fig. 6. Cambrian.

—— [*Conoceph.*] *formosus* Hartt. (See **Ptychoparia robbi** Hartt.)

—— [*Conoceph.* (*Ptychoparia*)] *gallatinensis* Meek, 1873; 6th Ann. Rept. U. S. Geol. Survey Territories, 1872, p. 485. Potsdam.

Referred by Walcott to *Ptychoparia oweni* Meek and Hayden.

—— [*Crepicephalus* (*Loganellus*]) **granulosus** Hall and Whitfield, 1877; U. S. Geol. Expl. 40th Par., Palæont., vol. 4, p. 214, pl. 2, figs. 1, 2, 3. Potsdam.

—— **granulosus** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 57.

—— [*Crepicephalus* (*Loganellus*)] **haguei** Hall and Whitfield, 1877; U. S. Geol. Expl. 40th Par., Palæont., vol. 4, p. 210, pl. 2, figs. 14, 15. Potsdam.

—— **haguei** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 57.

—— [*Lisostracus*] **haguei** Brögger, 1886; Geol. Föreningens Stockholm Förhandl., vol. 8, p. 202.

—— [*Conoceph.*] *halli* Hartt. (See **Ptychoparia orestes** Hartt.)

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Ptychoparia housensis Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 201, pl. 25, fig. 5. Middle Cambrian.

—— [*Conocoryphe* (*Concephalites*)] **kingii** Meek, 1870; Proc. Acad. Nat. Sci. Phila., vol. 22, p. 63.

—— [*Conocoryphe* (*Concephalites*)] **kingii** Meek, 1877; U. S. Geol. Expl. 40th Par., Palæont., vol. 4, p. 20, pl. 1, fig. 4.

—— [*Conocoryphe* (*Ptychoparia*)] **kingii** Meek, 1873; 6th Ann. Rept. U. S. Geol. Survey Territories, 1872, p, 487.

—— [*Conocoryphe* (*Ptychoparia*)] **kingii** White, 1876; U. S. Geog. and Geol. Surveys West 100th Mer., Palæont., vol. 4, p. 40, pl. 2, figs. 2 a, b, c.

—— [*Liostracus*] **kingii** Brögger, 1886; Geol. Föreningens Stockholm Förhandl., vol. 8, p. 205.

—— **kingii** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 193, pl. 27, figs. 4, 4 a. Middle Cambrian.

—— **læviceps** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 54, pl. 10, figs. 17, 18. Cambrian.

—— [*Conocephalites* (*Pterocephalus*)] **laticeps** Hall and Whitfield, 1877; U. S. Geol. Expl. 40th Par., Palæont., vol. 4, p. 67, 221, pl. 2, figs. 4-7. Cambrian.

—— [*Pterocephalus*] **laticeps** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 59.

—— ? **linnarssoni** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 47, pl. 9, figs. 18, 18 a. Cambrian.

—— [*Loganellus*] **logani** Devine, 1863; Canadian Naturalist, vol. 8, p. 95, figure. Potsdam.

—— [*Olenus?*] **logani** Billings, 1865; Pal. Foss., vol. 1, p. 201, figs. 185, 186.
Syn., [*Loganellus*] *quebecensis* Billings; *idem.*, p. 203.

—— **logani** Walcott, 1884; Bull. U. S. Geol. Survey, No. 10, p. 36.

—— [*Crepicephalus* (*Loganella*)] **maculosus** Hall and Whitfield, 1877; U. S. Geol. Expl. 40th Par., Palæont., vol. 4, p. 215, pl. 2, figs. 21, 25, 26 (?). Potsdam.

—— **maculosus** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, pp. 269, 271.

—— [*Conoceph.*] **minor** Shumard, 1863; Trans. Acad. Nat. Sci. St. Louis, vol. 2, p. 105. Potsdam.

—— (Undet.) trilobite Owen, 1848; Geol. Reconnoissance Chippewa Land Dist., p. 15, pl. 7, fig. 4.

—— [*Conoceph.*] **minor** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 149, pl. 8, figs. 1-4.

—— **minor** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol Survey, vol. 8, p. 91.

—— [*Conoceph.*] **minutus** Bradley, 1860; Am. Jour. Sci., 2d series, vol. 30, p. 24, 3 figs. Potsdam.

—— [*Conoceph.*] **minutus** Bradley, 1860; Canadian Naturalist, vol. 5, p. 420, figs. 1-3.

—— [*Conoceph.*] **minutus** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 150, pl. 8, figs. 5-7.

—— **minutus** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 91.

—— **minutus** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 21.

—— [*Conoceph.*] **miser** Billings, 1861; New or little known Sil. Foss., p. 12, fig. 14. Potsdam.

—— [*Conoceph.*] **miser** Billings, 1861; Geol. Vermont, vol. 2, p. 950, fig. 354.

—— [*Conoceph.*] **miser** Billings, 1863; Geol. Canada, p. 286, fig. 393.

—— [*Conoceph.*] **miser** Billings, 1865; Pal. Foss., vol. 1, p. 12, fig. 14.

—— **miser** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 199, pl. 27, fig. 2.

—— [*Crepicephalus* (*Loganella*)] **montanensis** Whitfield, 1876; Rept. Recon. Upper Missouri, p. 141, pl. 1, figs. 1, 2. Potsdam.

—— **montanensis** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, pp. 53, 56.

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Ptychoparia mucronatus Shaler and Foerste, 1888; Bull. Mus. Comp. Zool. Harvard Coll., vol. 16, p. 37, pl. 2, fig. 21. Cambrian.

—— [*Conoceph.*] **nasutus** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 155, pl. 7, figs. 3–9. Potsdam.

—— [*Conoceph.*] *neglectus.* (See **Ptychoparia tener.**)

—— [*Crepicephalus* (*Loganella*)] **nitidus** Hall and Whitfield, 1877; U. S. Geol. Expl. 40th Par., Palæont., vol. 4, p. 212, pl. 2, figs. 8–10. Cambrian.

Syn., *Crepicephalus* [*Loganella*] *simulator* (Hall and Whitfield) Walcott.

—— **nitidus** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 57.

—— **occidentalis** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 51, pl. 10, fig. 5. Cambrian.

—— [*Conoceph.*] **orestes** Hartt, 1868; Acadian Geology, p. 649, fig. 225. St. John.

Syn., *Conoceph. halli* (Hartt) Walcott; Bull. U. S. Geol. Survey, No. 10, p. 40.
Conoceph. thersites (Hartt) Walcott; Bull. U. S. Geol. Survey, No. 10, p. 40.

—— **orestes** var. **thersites** Walcott, 1884; Bull. U. S. Geol. Survey, No. 10, p. 40.

Syn., *orestes* Walcott, 1884; Bull. U. S. Geol. Survey, No. 10, p. 39, pl. 5, figs. 3, 3 a.

—— [*Solenopleura*] **orestes** Matthew, 1887; Trans. Royal Soc. Canada, vol. 4, p. 154. pl. 2, figs. 4 a–e.

—— [*Pterocephalus*] **occidens** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 58, pl. 9, fig. 21. Cambrian.

—— [*Conoceph.*] **ouangondiana** Hartt, 1868; Acadian Geology, p. 651, fig. 226. St. John.

—— **ouangondiana** Walcott, 1884; Bull. U. S. Geol. Survey, No. 10, p. 37, pl. 5, figs. 4, 4 a–f.

—— **ouangondiana** var. **aurora** (Hartt) Walcott; Bull. U. S. Geol. Survey, No. 10, p. 38, pl. 5, fig. 5.

—— [*Liostracus*] **ouangondiana** Matthew, 1887; Trans Royal Soc. Canada, p. 138.

—— **oweni** (Meek and Hayden) Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 55, pl. 10, figs. 3, 3 a. (See **Agraulus oweni** Meek and Hayden.)

The following species are referred by Walcott (Mon. U. S. Geol. Survey, vol. 8, p. 55) to *Ptychoparia oweni:*

Arionellus oweni Meek and Hayden, 1862; Am. Jour. Sci., 2d series, vol. 33, p. 74.

Agraulos oweni Meek and Hayden, 1864; Pal. Upper Missouri, p. 9, figs. a–c, pl. 1, fig. 4.

Conocoryphe (*Ptychoparia*) *gallatinensis* Meek, 1870; 6th Ann. Rept. U. S. Geol. Survey Territories, 1872, p. 485.

Crepicephalus (*Loganella*) *centralis* Whitfield, 1880; Geol. Resources Black Hills, Dakota, p. 341, pl. 2, figs. 21–24.

—— [*Conoceph.*] **oweni** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 155, pl. 8, figs. 17–20. Potsdam.

—— [*Crepicephalus* (*Loganella*)] **planus** Whitfield, 1877; Prelim. Rept. Pal. Black Hills, p. 11. Potsdam.

—— [*Crepicephalus*] **planus** Whitfield, 1880; Geol. Black Hills Dakota, p. 343, pl. 2, fig. 20.

—— ? **pernasutus** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 49, pl. 10, figs. 8, 8 a, b. Cambrian.

—— [*Conoceph.*] **perseus** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 153, pl. 7, figs. 17–22; pl. 8, fig. 33. Potsdam.

—— **piochensis** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 201, pl. 26, fig. 2–2 a, b; pl. 28, figs. 1–1 a–e. Middle Cambrian.

—— ? **prospectensis** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 46, pl. 9, fig. 20. Cambrian.

—— ? **prospectensis** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 202, pl. 27, fig. 5.

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Ptychoparia quadrangularis Whitfield. The specific name of *Conoceph. quadratus* being preoccupied, Prof. R. P. Whitfield substitutes that of *quadrangularis* for the species.

—— [*Crepicepalus* (*Loganella*)] **quadrans** Hall and Whitfield, 1877; U. S. Geol. Expl. 40th Par., Palæont., vol. 4, p. 238, pl. 2, figs. 11-13.

—— **quadrans** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 199, pl. 29, figs. 4-4 a, b. Cambrian.

—— [*Conoceph.*] *quadratus*. (See **Ptychoparia quadrangularis**.)

—— [*Conoceph.*] **quadratus** Hartt, 1868; Acadian Geology, p. 654. St. John.

—— **quadratus** Walcott, 1884; Bull. U. S. Geol. Survey, No. 10, p. 39, pl. 5, fig. 1.

—— [*Conoceph.?*] **quadratus** Whitfield, 1880; Ann. Rept. Geol. Survey, Wisconsin, 1879, p. 47.

—— [*Conoceph.?*] **quadratus** Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 180, pl. 1, figs., 15, 16. (See **Ptychoparia quadrangularis** Whitfield.)

—— [*Conoceph.*] *robbi* Hartt, 1868; Acadian Geology, p. 648. St. John.

Syn., *Conoceph. formosa* (Hartt) Walcott; Bull. U. S. Geol. Survey, No. 10, p. 36.

—— *robbi* Walcott, 1884; Bull. U. S. Geol. Survey, No. 10, p. 36, pl. 6, figs. 1, 1 a.

—— [*Solenopleura*] **robbi** Matthew, 1887; Trans. Royal Soc. Canada, vol. 4, p. 153, pl. 2, figs. 3 a-l; fig. 4 a-e.

—— **rogersi** Walcott, 1884; Bull. U. S. Geol. Survey, No. 10, p. 47, pl. 7, fig. 2. Lower Cambrian.

—— [*Conoceph.*] **shumardi** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 154, pl. 7, figs. 1-2; pl. 3, figs. 19, 32. Potsdam.

—— **similis** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 52, pl. 10, figures. Cambrian.

—— **similis** var. **robustus** Walcott; *idem.*, p. 53, pl. 1, figs. 9, 9 a.

—— [*Conoceph.*] **subcoronatus** Hall and Whitfield, 1877; U. S. Geol. Expl. 40th Par., Palæont., vol. 4, p. 237, pl. 2, fig. 1.

—— **subcoronatus** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 205, pl. 28, fig. 4. Middle Cambrian.

—— [*Conoceph.*] **teucer** Billings, 1861; New or little known Sil. Foss., p. 12, fig. 16.

—— [*Conoceph.*] **teucer** Billings, 1861; Geol. Vermont, vol. 2, p. 951, fig. 356.

—— [*Conoceph.*] **teucer** Billings, 1865; Pal. Foss., vol. 1, p. 13, fig. 16.

—— [*Conoceph.*] **teucer** Billings, 1863; Geol. Canada, p. 286, fig. 295.

—— **teucer** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 197, pl. 26, fig. 3. Middle Cambrian.

—— [*Conoceph.*] **tener** Hartt, 1868; Acadian Geology, p. 652. St. John.

Syn., *Conoceph. neglectus* (Hartt) Walcott, 1884; Bull. U. S. Geol. Survey, No. 10, p. 41.

—— **tener** Walcott, 1884; Bull. U. S. Geol. Survey, No. 10, p. 41, pl. 5, figs. 6, 6 a, b.

—— [*Conoceph.*] *thersites*. (See **Ptychoparia orestus** Hartt.)

—— *trilineatus*. (See **Atops trilineatus**, **Conocoryphe trilineatus**, **Conocephalites trilineatus**, **Calymene beckii**, **Triarthrus beckii**.)

—— [*Crepicephalus* (*Loganella*)] **unisulcatus** Hall and Whitfield, 1877; U. S. Geol. Expl. 40th Par., Palæont., vol. 4, p. 216, pl. 2, figs. 22, 23. Cambrian.

—— **unisulcatus** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 58.

—— [*Conoceph.*] **verucosus** Whitfield, 1884; Bull Am. Mus. Nat. Hist., vol. 1, p. 146, pl. 14, fig. 12. Potsdam.

—— [*Conoceph.*] **vulcanus** Billings, 1861; New or little known Sil. Foss., p. 14, fig. 17.

—— [*Conoceph.*] **vulcanus** Billings, 1861; Geol. Vermont, vol. 2, p. 952, fig. 357.

—— [*Conoceph.*] **vulcanus** Billings, 1863; Geol. Canada, p. 286, fig. 296.

—— [*Conoceph.*] **vulcanus** Billings, 1865; Pal. Foss., vol. 1, p. 14, fig. 17.

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Ptychoparia vulcanus Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 196, pl. 26, figs. 4, 4 a. Middle Cambrian.

Compare *Ptychoparia adamsi*.

—— [*Conoceph.*] **winona** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 161, pl. 7, figs. 26–28. Potsdam.

—— [*Conoceph.*] **zenkeri** Billings, 1860; Canadian Naturalist, vol. 5, p. 305, fig. 4. Quebec.

—— [*Conoceph.*] **zenkeri** Billings, 1865; Pal. Foss., vol. 1, p. 398, fig. 375.

Remopleurides Portlock, 1843; Rept. Geol. Londonderry, etc., p. 254.

Type, *Remopleurides colbii* Portlock.

Syn., *Caphyra* Barrande, 1846; Notice Prélim., p. 32.

Amphytryon Corda, 1847; Prodr., p. 228.

—— **affinis** Billings, 1865; Pal. Foss., vol. 1, p. 325, fig. 313. Quebec.

—— **canadensis** Billings, 1865; Pal. Foss., vol. 1, p. 182, fig. 164. Chazy.

—— **panderi** Billings, 1865; Pal. Foss., vol. 1, p. 293, fig. 283. Quebec.

—— ? **schlotheimi** Billings, 1865; Pal. Foss., vol. 1, p. 294, fig. 284. Quebec.

Syn., *Paradoxides* or *Olenellus* Billings, 1863; Geol. Canada, pp. 871, 872.

—— **striatulus** Walcott, 1875; Cincinnati Quart. Jour. Sci., vol. 2, p. 347, fig. 27, 27 a, b. Trenton.

Sao Barrande, 1846; Notice Prélim. Syst. Sil. Bohême, p. 13.

—— ? **lamottensis** Whitfield, 1886; Bull. Am. Mus. Nat. Hist. New York, vol. 1, p. 334, pl. 33, figs. 9–11. Birdseye Limestone.

Shumardia Billings, 1862; Pal. Foss., vol. 1, p. 92.

Type, *Shumardia granulosa* Billings.

The generic name therein suggested by Mr. E. Billings for a minute Trilobite includes a specimen having an expanding glabella, with two anterior side nodules, simular to those of *Battus pusillus* Sar, the genus being allied to *Agnostus*, differing therefrom in having a regularly ribbed pygidium, similar to that of an *Asaphus*. Comparing Mr. E. Billings's type, *Shumardia granulosa*, with *Conophrys salopiensis* Galloway (Quart. Jour. Geol. Soc. London, vol. 33, p. 667, pl. 12, fig. 7), which W. C. Brögger (Sil. Etagen 2 und 3, p. 125) refers to as a synonym to *Battus pusillus*, we find a similar characteristic in the glabella. The pygidium of *Shumardia granulosa* has however a more semi-oval form, with a greater number of axis rings and an additional number of ribs on the side lobes.

The head of *Shumardia granulosa* differs from *Battus pusillus* in having a groove, which runs from the anterior front of the glabella to the frontal margin of the head, a characteristic of some species of *Agnostidæ* (*vid.* Brögger, Sil. Etagen 2 und 3, pl. 1, fig. 10).

Mr. Billings remarks "that in some specimens this furrow has at the bottom a small triangular tubercle, giving the glabella the appearance of having a projecting angular process in the middle of its front." I am more inclined to view this triangular tubercle as a point of attachment for the muscles of the jaws, and not as a process for the attachment of antennæ.

Mr. E. Billings in the same book gives a description of a second species, which he calls *Shumardia glacialis*, figured p. 283, fig. 270. The species is represented with three glabella furrows, and should not be included in the genus *Shumardia*.

If these forms are not embryonic, against which in the case of *Conophrys salopiensis* Mr. C. Callaway dissents on account of the constant size of the heads and the absence of the facial sutures amongst the larger specimens, I would advocate the acceptance of the new genus *Shumardia* amongst the *Agnostidæ* for such species as *Shumardia granulosa* and *Battus pusillus* to replace the latter generic term of *Conophrys*.

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Solenopleura Angelin, 1854; Palæont. Scand., p. 26.

Type, *Solenopleura kolometopa* Angelin.

Diagnosis: Glabella prominent, with three distinct furrows; fixed cheeks, elevated especially in the middle; front limb convex; occipital ring bearing a tubercle; genal angles pointed; thorax, pleuræ bluntly rounded; pygidium small with few segments; surface of shell granulated with or without scattered tubercles.

—— **acadia** Whiteaves, 1885; Trans. Royal Soc. Canada, vol. 3, p. 76, pl. 7, fig. 15. Cambrian.

—— **acadia** Whiteaves, 1887; Trans. Royal Soc. Canada, vol. 4, p. 157, pl. 2, figs. 5 a, b, c.

—— **acadia** var. **elongata** Matthew, 1887; *idem.*, p. 159, pl. 1, fig. 6.

—— **bombifrons** Matthew, 1886; Trans. Royal Soc. Canada, vol. 2, p. 156, figs. 5–5 a b. St. John.

—— **communis** Billings, 1874; Pal. Foss., vol. 2, p. 72. Potsdam.

—— **communis** Matthew, 1886; Trans. Royal Soc. Canada, vol. 2, p. 155, figs. 4–4 a, b.

—— **nana** Ford, 1878; Am. Jour. Sci., 3d series, vol. 15, p. 126. Potsdam.

—— **nana** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 214, pl. 27, fig. 3.

—— ? **nana** Walcott, 1887; Am. Jour. Sci., 3d series, vol. 34, p. 196, pl. 1, figs. 1–1 d. Cambrian.

—— **orestes** (Hartt) Matthew, 1887; Trans. Royal Soc. Canada, vol. 4, p. 154, pl. 2, figs. 4 a–e.

Syn., *robbi* (Hartt) Matthew, 1887; Trans. Royal Soc. Canada, vol. 4, p. 153, pl. 2, figs. 3 a–l and figs. 4 a–e. St. John.

—— ? **tumida** Walcott, 1887; Am. Jour. Sci., 3d series, vol. 34, p. 196, pl. 1, fig. 2, 2 a. Cambrian.

Sphærexochus Beyrich, 1845; Ueber einige böhmische Trilobiten, p. 19.

Type, *Sphærexochus mirus*.

—— **canadensis** Billings, 1866; Catalogue Sil. Foss. Anticosti, p. 64, fig. 21.

—— **mirus** (Beyrich) Roemer, 1860; Die Sil. Fauna W. Tennessee, p. 81, pl. 5, fig. 20. Niagara.

—— **parvus** Billings, 1865; Pal. Foss., vol. 1, p. 180, fig. 161. Chazy and Trenton.

—— **romingeri** Hall, 1862; Geol. Rept. Wisconsin, p. 434. Niagara.

Syn., *mirus* Hall (not Beyrich), 1867; 20th Rept. New York State Cab. Nat. Hist., p. 334, pl. 21, figs. 4–7.

—— **romingeri** Hall, 1867; 20th Rept. New York State Cab. Nat. Hist., p. 375, pl. 22, figs. 4–7.

—— **romingeri** Hall, 1870; 20th Rept. New York State Cab. Nat. Hist., p. 425, pl. 21, figs. 4–7 (rev. ed.).

—— **romingeri** Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 311, pl. 21, figs. 1–3.

—— **romingeri** ? Hall; 28th Rept. New York State Mus. Nat. Hist., p. 32, pl. 32, fig. 16.

—— **romingeri** Meek and Worthen, 1875; Geol. Survey Illinois, vol. 6, p. 510, pl. 24, fig. 4.

Sphærocoryphe Angelin, 1854; Palæont. Scand., p. 65.

Type, *Sphærocoryphe dentata* Angelin.

—— **robustus** Walcott, 1875; Cincinnati Quart. Jour. Sci., vol. 2, p. 273, figs. 18 a, b. Trenton.

—— **salteri** Billings, 1866; Catalogue Sil. Foss. Anticosti, p. 63.

Symphysurus Goldfuss, 1843; Jahrb. für Mineral., 1843, p. 552.

—— ? **goldfussi** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 95, pl. 12, fig. 16. Pogonip.

Telephus Barrande, 1852; Syst. Sil. Bohême, vol. 1, p. 890.

—— **americanus** Billings, 1865; Pal. Foss., vol. 1, p 291, figs. 281. Quebec.

*Teratasp*is Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 223. (See **Lichas** and **Acidaspis**.)

—— *grandis*. (See **Lichas** [*Teratasp*is] **grandis** Hall.)

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Terataspis eriops. (See **Lichas** [*Conolichas*] **eriops** Hall.)
Thaleops Conrad, 1843; Proc. Acad. Nat. Sci. Phila., vol. 1, p. 332.
—— *ovatus* Conrad. (See **Illænus ovatus.**)
Triarthrella Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 177.
—— **auroralis** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 177, pl. 9, fig. 13. Potsdam.
Triarthrus Green, 1832; Monthly Am. Jour. Geol., vol. 1, p. 560 (June). Green, 1832; Mon. Tril. North America, p. 86.
Type, *Triarthrus beckii* Green.
—— **beckii** Green, 1832; Monthly Am. Jour. Geol., vol. 1, p. 560, pl. 1, fig. 3 (June).
—— **beckii** Green, 1832; Mon. Tril. N. A., p. 86, cast 34, pl. 1, fig. 3.
—— **beckii** Harlan, 1835; Trans. Geol. Soc. Penn., vol. 1, p. 205, pl. 15, fig. 6.
Syn., [*Paradoxides*] *triarthrus* Harlan, 1835; Trans. Geol. Soc. Penn., vol. 1, pl. p. 264, 15, fig. 5.
[*Paradoxides*] *arcuatus* Harlan, 1835; Trans. Geol. Soc. Penn., vol. 1, p. 265, pl. 15, figs. 1–3.
—— **beckii** Harlan, 1835; Med. Phys. Researches, p. 400, pl., fig. 6.
Syn., [*Paradoxides*] *triarthrus* Harlan, 1835; Med. Phys. Researches, p. 401, pl., fig. 5.
[*Paradoxides*] *arcuatus* Harlan, 1835; Med. Phys. Researches, p. 402, pl., figs. 1–3.
—— **beckii** Green, 1835; Suppl. Mon. Tril. N. A., p. vii.
—— [*Paradoxides*] **beckii** Hall, 1838; Am. Jour. Sci., 1st series, vol. 33, p. 142, fig. 2.
Syn., *Paradoxides eatoni* Hall, 1838; Am. Jour. Sci., 1st series, vol. 33, p. 142, fig. 2.
—— **beckii** Green, 1838; Am. Jour. Sci., 1st series, vol. 33, p. 344.
—— **beckii** Mather, 1842; Geol. New York, 1st Geol. Dist., p. 390, fig. 24 (1).
—— **beckii** Emmons, 1842; Geol. New York, 2d Geol. Dist., p. 399, fig. 110 (1).
—— **beckii** Vanuxem, 1843; Geol. New York., 3d Geol. Dist., p. 57, fig. 8 (1).
—— **beckii** Hall. 1843; Geol. New York, 4th Geol. Dist., p. 504.
—— [*Calymene*] **beckii** Hall, 1847; Pal. New York, vol. 1, p. 237, pl. 64, figs. 2 a–e.
—— [*Calymene*] **beckii** Hall, 1847; Pal. New York, vol. 1, p. 250, pl. 66, figs. 2 a–k (not pl. 67, figs. 4 a–e, *Atops trilineatus*).
Syn., *Atops trilineatus* (Emmons) Hall, 1847; Pal. New York, vol. 1, p. 237.
—— [*Calymene*] **becki** Hall, 1848; Am. Jour. Sci., 2d series, vol. 5, p. 322, figs. 1 a, b, 2 a–g.
—— **becki** Emmons, 1848; Am. Assoc. Adv. Sci., p. 17.
—— **beckii** Haldeman, 1848; Am. Jour. Sci., 2d series, vol. 8, p. 137.
—— **beckii** Emmons, 1855; Am. Geology, vol. 1, pt, 2, p. 214, pl. 15, fig. 12.
—— [*Calymene*] **beckii** Rogers, 1858; Geol. Survey Penn., vol. 2, p. 820, fig. 613.
—— **beckii** Barrande, 1861; Soc. Géol. France, 2d series, p. 269, pl. 5, figs. 11, 12.
—— **beckii** Logan, 1863; Geol. Canada, p. 202, fig. 200.
—— **beckii** Miller, 1874; Cincinnati Quart. Jour. Sci., vol. 1, p. 146.
—— **becki** Walcott, 1876; Trans. Albany Inst., vol. 10, p. 23, pl. 2, figs. 1–16. Trenton.
—— [*Brongniartia*] **carcinodea** Eaton, 1832; Am. Jour. Sci., 1st series, vol. 22, p. 166 (March 6).
—— [*Brongniartia*] **carcinodea** Eaton, 1832; Geol. Text Book, p. 33, pl. 1, fig. 3.
—— **canadensis** Smith, 1861; Canadian Jour., vol. 6, p. 275. Hudson.
—— **fischeri** Billings, 1861; Pal. Foss., vol. 1, p. 291, fig. 280. Quebec.
—— **glaber** Billings, 1859; Canadian Naturalist, vol. 4, p. 382. Utica.
—— **glaber** Billings, 1863; Geol. Canada, p. 202, fig. 198.
—— **spinosus** Billings, 1859; Canadian Naturalist, vol. 4, p. 382. Trenton.
—— **spinosus** Billings, 1863; Geol. Canada, p. 202, fig. 199.
—— **spinosus** Ami, 1882; Trans. Ottawa Nat. Club, vol. for 1882–'83, p. 88, pl. 1, figure.

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Triarthrus trimerus Green, 1832; Monthly Am. Jour. Geol., vol. 1, p. 560. (See **Homalonotus delphinocephalus** and **H. jacksoni.**)

Trinucleus Lhwyd, 1698; Lithophyacii Britannici Ichnographia, Epistola 1. Murchison, Silurian System, 1839, p. 659.

Sir R. I. Murchison has revived this old name of Lhwyd's from classical feelings, and all subsequent palæontologists have adopted it. Lhwyd's description meant no more than the general name of Trilobite of the more modern writers, and could not, except by courtesy, set aside Dr. Jacob Green's genus *Cryptolithus*.

—— **bellulus** Ulrich, 1878; Jour. Cincinnati Soc. Nat. Hist., vol. 1, p. 99, pl. 4, fig. 15.

—— [*Nuttainia*] **concentrica** Eaton, 1832; Geological Text Book, p. 34, pl. 1, fig. 2.

Syn., *Trilobite* Bigsby, 1825; Annals Lyceum Nat. Hist. New York, vol. 1, pt. 2, p. 214, pl. 15, fig. 1. Trenton and Hudson.

Cryptolithus tessellatus Green, 1832; Mon. Tril. N. A., p. 73, cast 38, pl. 1, fig. 4.

Cryptolithus tessellatus Green, 1832; Monthly Am. Jour. Geol., vol. 1, pl. 1, fig. 4.

—— **concentrica** Hall, 1847; Pal. New York, vol. 1, pp. 249, 255, pl. 65, figs. 4 a, b; pl. 67, figs. 1 a–h.

—— **concentrica** Emmons, 1855; Am. Geology, vol. 1, pt. 2, p. 212, pl. 17, fig. 1.

—— **concentrica** Chapman, 1858; Canadian Jour., vol. 3, p. 514.

—— **concentrica** Billings, 1861; Geol. Vermont, vol. 1, p. 300, fig. 215.

—— **concentrica** Miller, 1874; Cincinnati Quart. Jour. Sci., vol. 1, p. 126.

Zacanthoides Walcott, 1887; Am. Jour. Sci., 3d series, vol. 36, p. 165.

Type, *Zacanthoides spinosus* Walcott.

—— [*Dicellocephalus?*] **flagricauda** White, 1874; Prelim. Rept. Invt. Foss. Geog. and Geol. Survey West 100th Mer., p. 12. Cambrian.

—— [*Dicellocephalus?*] **flagricauda** White, 1877; U. S. Geog. and Geol. Survey West 100th Mer., vol. 4, p. 60, pl. 3, figs. 8 a, b.

—— [*Olenoides*] **flagricauda** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 185, pl. 25, fig. 4.

—— **flagricauda** Walcott, 1888; Am. Jour. Sci., 3d series, vol. 36, p. 165.

—— [*Olenoides*] **levis** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 187, pl. 25, figs. 3, 3 a. Cambrian.

—— **levis** Walcott, 1888; Am. Jour. Sci., 3d series, vol. 36, p. 165.

—— [*Ogygia?*] **spinosus** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 63, pl. 9, fig. 22. Middle Cambrian.

—— [*Olenoides*] **spinosus** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 184, pl. 25, figs, 6, 6 a.

—— [*Embolimus*] **spinosus** (Rominger) Walcott, 1888; Am. Jour. Sci., 3d series, vol. 36, p. 164.

—— **spinosus** Walcott, 1888; Am. Jour. Sci., 3d series, vol. 36, p. 165.

—— [*Olenoides*] **typicalis** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 183, pl. 25, figs. 2, 2 a. Middle Cambrian.

—— **typicalis** Walcott, 1888; Am. Jour. Sci., 3d series, vol. 36, p. 165.

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PART III.

CATALOGUE OF NON-TRILOBITES.

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PART III.

NON-TRILOBITIC GENERA AND SPECIES.

MEROSTOMATA.

EURYPTERIDÆ.

EURYPTERUS De Kay, 1825; Annals Lyceum Nat. Hist., vol. 1, p. 375.
DOLICHOPTERUS Hall, 1859; Palæont. New York, vol. 3, p. 414.
ECHINOGNATHUS Walcott, 1882; Am. Jour. Sci., 3d series, vol. 23, p. 213.
ADELOPHTHALMUS Jordan and Meyer, 1854; Crust. Steinkohl. Saarb., p. 8.
GLYPTOSCORPIUS Peach, 1880; Trans. Royal Soc. Edinb., vol. 30, p. 516.
ARTHROPLEURA Jordan and Meyer, 1854; Crust. Steinkohl. Saarb., p. 13.

PTERYGOTIDÆ.

PTERYGOTUS Agassiz, 1844; Mon. Poissons Foss., note, p. xix.
SLIMONIA Page, 1856; Advance Text-Book Geology, p. 135.
STYLONURUS Page, 1856; Advance Text-Book Geology.

SYNZIPHOSURA.

ACANTHOTELSON Meek and Worthen, 1865; Proc. Acad. Nat. Sci. Phila., vol. 17, p. 46; Geol. Survey Illinois, vol. 2, 1866, p. 399.

XIPHOSURA.

CYCLIDÆ.

CYCLUS De Koninck, 1841; Mém. Acad. Sci. Belgique, vol. 14, p. 13.
DIPELTIS Packard, 1885; American Naturalist, vol. 19, p. 293.

BUNODIDÆ.

BUNODES Eichwald, 1854; Beiträge Geol. u. Pal. Russ., p. 131.
HEMISAPIS Woodward, 1865; Quart. Jour. Geol. Soc. London, vol. 21, p. 490.
EXAPINURUS Nieszkowski, 1859; Archiv Nat. Liv-, Esth- u. Kurl., vol. 1, p. 380.
PSEUDONISCUS Neiszkowski, 1859; Archiv Nat. Liv-, Esth- u. Kurl., vol. 1, p. 381.

LIMULIDÆ.

BELINURUS Koenig, 1820; Icones Foss. Sectiles, pl. 18, fig. 230.
PRESTWICHIA Woodward, 1887; Quart. Jour. Geol. Soc. London, vol. 23, p. 32.

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LIMULUS Müller, 1785; Entomostraca, etc., p. 124.
PROTOLIMULUS Packard, 1886; Mem. Nat. Acad. Sci., vol. 3, p. 150.
NEOLIMULUS Woodward, 1868; Geol. Mag., vol. 5, p. 1.

PHYLLOPODA.

CERATIOCARIDÆ.

HYMENOCARIS Salter, 1852; Rept. 22d Meeting Brit. Assoc. Adv. Sci., Trans. Sec., p. 56.
CERATIOCARIS McCoy, 1849; Annals Mag. Nat. Hist. London, 2d series, vol. 4, p. 412.
ECHINOCARIS Whitfield, 1880; Am. Jour. Sci., 3d series, vol. 19, p. 34.
DIDYOCARIS Salter, 1860; Annals Mag. Nat. Hist. London, 3d series, vol. 5, p. 161.
DITHYOCARIS (Scouler) Portlock; Geol. Rept. Londonderry, etc., 1843, p. 313.
PROTOCARIS Walcott, 1884; Bull. U. S. Geol. Survey, No. 10, p. 50.
ELYMOCARIS Beecher, 1884; 2d Geol. Survey Penn., vol. PPP., p. 13.
TROPIDOCARIS Beecher, 1884; 2d Geol. Rept. Penn., vol. PPP., p. 15.
PHYSOCARIS Salter, 1860; Annals Mag. Nat. Hist. London, 3d series, vol. 5, p. 159.
PHASGANOCARIS Novák, 1886; Sitzungsb. böhm. Gesell., 1886, p. 498.
ACANTHOCARIS Peach, 1882; Trans. Royal Soc. Edinb., vol. 30, p. 511.

DISCINOCARIDÆ.

DISCINOCARIS Woodward, 1866; Quart. Jour. Geol. Soc. London, vol. 22, p. 504.
SPATHIOCARIS Clarke, 1882; Am. Jour. Sci., 3d series, vol. 23, p. 477.
PHOLADOCARIS Woodward, 1882; Geol. Mag., decade 3, vol. 9, p. 388.
ELLIPSOCARIS Woodward, 1882; Geol. Mag., decade 3, vol. 9, p. 444.
LISGOCARIS Clarke, 1882; Am. Jour. Sci., 3d series, vol. 23, p. 478.
CARDIOCARIS Woodward, 1882; Geol. Mag., decade 3, vol. 9, p. 386.
DIPTEROCARIS Clarke, 1883; Am. Jour. Sci., 3d series, vol. 23, p. 121.
PTEROCARIS Barrande, 1872; Syst. Sil. Bohême, vol. 1, suppl., p. 464.
CRESCENTELLA Barrande, 1872; Syst. Sil. Bohême, vol. 1, suppl., p. 507.
APTYCHOPSIS Barrande, 1872; Syst. Sil. Bohême, vol. 1, suppl., p. 455.
PELTOCARIS Salter, 1863; Quart. Jour. Geol. Soc. London, vol. 19, p. 87.
PINNOCARIS Etheridge, 1878; Proc. Royal Phys. Soc., Edinb., vol. 4, p. 167.
PTYCHOCARIS Novák, 1885; Sitzungsb. böhm. Gesell., 1885, p. 343.

RHINOCARIDÆ.

RHINOCARIS Clarke, 1888; Palæont. New York, vol. 7, p. lviii.
COLPOCARIS Meek, 1871; Proc. Acad. Nat. Sci. Phila., vol. 23, p. 334.
SOLENOCARIS Meek, 1871; Proc. Acad. Nat. Sci. Phila., vol. 23, p. 335. Name should be changed, preoccupied by J. Young. See STRIGOCARIS.
MESOTHYRA Hall, 1888; Palæont. New York, vol. 7, pp. lvi, 187.
SACOCARIS Salter, 1868; Proc. Geol. Polytech. Soc., vol. 4, p. 588.
LINGULOCARIS Salter, 1866; Mem. Geol. Survey, vol. 3, pp. 252, 253, and 294.
SOLENOCARIS Young, 1868; Proc. Nat. Hist. Soc. Glasgow, vol. 1, p. 171.
ROSTROCARIS Kinnear, 1887; Trans. Edinb. Geol. Soc., vol. 5, p. 417.
CARYOCARIS Salter, 1863; Quart. Jour. Geol. Soc. London, vol. 19, p. 139.
ENTOMIDELLA Jones, 1873; Annals Mag. Nat. Hist., London, 4th series, vol. 11, p. 416.
ARCHÆOCARIS Meek, 1872; Proc. Acad. Nat. Sci. Phila., vol. 23, p. 335.
MYOCARIS Salter, 1864; Quart. Jour. Geol. Soc. London, vol. 20, 1864, p. 292.
ESTHERIA Rüppell, 1857; Mus. Senckenberg, vol. 2, p. 119.
LEAIA Jones, 1882; Mon. Fossil Estheria, p. 115.
SCHIZODISCUS Clarke, 1888; Palæont. New York, vol. 7, p. 207.

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BIVALVED ENTOMOSTRACA.

CYPRIDINIDÆ.

CYPRIDINA Milne-Edwards, 1838; Lamarck's Anim. s. Vert., vol. 5, p. 178.
CYPRIDINELLA Jones and Kirkby, 1874; Mon. Carboniferous Entom., p. 21.
CYPRIDELLINA Jones and Kirkby, 1874; Mon. Carboniferous Entom., p. 25.
SULCUNA Jones, 1873; Quart. Jour. Geol. Soc. London, vol. 29, p. 411.
CYPRELLA De Koninck, 1841; Mém. Acad. Royale Bruxelles, vol. 14, p. 19.
BRADYCINETUS Sars, 1865; Översigt af Norges Marine Ostracoder.
PHILOMEDES Lilljeborg, 1853; Crust. in Scania Occurrentibus, p. 175.
RHOMBINA Jones and Kirkby, 1874; Mon. Carboniferous Entom., p. 43.

ENTOMOCONCHIDÆ.

ENTOMOCONCHUS McCoy, 1839; Jour. Geol. Soc. Dublin, vol. 2, p. 91.
OFFA Jones and Kirkby, 1874; Mon. Carboniferous Entom., p. 53.

POLYCOPIDÆ.

POLYCOPE Sars, 1865; Översigt af Norges Marine Ostracoder.

ENTOMIDIDÆ.

ENTOMIS Jones, 1861; Mem. Geol. Survey Scotland, Expl. map 32, p. 137.

CYTHERELLIDÆ.

CYTHERELLA Jones and Bosquet, 1848 and 1852.
CYTHERELLINA Jones and Holl, 1869; Annals Mag. Nat. Hist., London, 4th series, vol. 3, p. 215.
CYTHERINA Lamarck, 1818; Animaux sans Vert., vol. 5, p. 125.
ÆCHMINA Jones and Holl, 1869; Annals Mag. Nat. Hist., London, 4th series, vol. 3, p. 217.

LEPERDITIDÆ.

LEPERDITIA Rouault, 1851; Bull. Soc. Géol. France, 2d series, vol. 8, p. 377.
BERNIX Jones, 1884; Proc. Berwickshire Nat. Club, vol. 10, p. 316.
ISOCHILINA Jones, 1858; Annals Mag. Nat. Hist., London, 3d series, vol. 1, p. 248.
PRIMITIA Jones and Holl, 1865; Annals Mag. Nat. Hist., London, 3d series, vol. 16, p. 416.
BEYRICHIA McCoy, 1846; Synopsis Sil. Foss. Ireland, p. 57.
BEYRICHIELLA Jones and Kirkby, 1886; Geol. Mag., n. s., decade 3, vol. 3, p. 438.
KIRKBYA Jones, 1869; Annals Mag. Nat. Hist., London, 4th series, vol. 3, p. 223.
MOOREA Jones and Kirkby, 1867; Annals Mag. Nat. Hist., London, 4th series, vol. 3, p. 225.
PHREATURA Jones and Kirkby, 1886; Quart. Jour. Geol. Soc. London, vol. 42, p. 507.
STREPULA Jones and Holl, 1886; Annals Mag. Nat. Hist., London, 5th series, vol. 17, p. 403.
BOLLIA Jones and Holl, 1886; Annals. Mag. Nat. Hist., London, 5th series, vol. 17, p. 360.
KLŒDINIA Jones and Holl, 1886; Annals Mag. Nat. Hist., London, 5th series, vol. 17, p. 362.
BEYRICHIOPSIS Jones and Kirkby, 1886; Geol. Mag., decade 3, vol. 3, p. 434.
APARCHITES Jones, 1889; Annals Mag. Nat. Hist., 6th series, vol. 3, p. 385.
PRIMITOPSIS Jones, 1887; Notes on some Sil. Ostracoda from Gothland, p. 5.

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Placentura Jones and Holl, 1886; Annals Mag. Nat. Hist., London, 5th series, vol. 17, p. 407.
Kyamodes Jones, 1888; Annals Mag. Nat. Hist., London, 6th series, vol. 2, p. 295.
Cyprosis Jones, 1881; Geol. Mag., decade 2, vol. 8, p. 338.
Cyprosina Jones, 1881; Geol. Mag., decade 2, vol. 8, p. 338.
Octonaria Jones, 1887; Annals Mag. Nat. Hist., London, 5th series, vol. 19, p. 404.

CYPRIDÆ.

Aglaia Brady, 1867; Challenger Exped., Rept. on Ostracoda, p. 33.
Candona Baird, 1850; History Brit. Entomostraca, p. 159.
Argillæcia Sars, 1865; Öfversigt af Norges Marine Ostracoder.
Macrocypsis Brady, 1867; Intellectual Observ., vol. 12, p. 119.
Bathocypsis Brady, 1880; Challenger Exped., Rept. on Ostracoda, p. 45.
Bairdia McCoy, 1844; Synopsis Carboniferous Foss. Ireland, p. 164.

DARWINULIDÆ.

Darwinula (Brady and Robertson) Jones, 1885; Quart. Jour. Geol. Soc., vol. 41, p. 346. Name changed from preoccupied term Darwinella (Ann. Mag. Nat. Hist., 4th series, vol. 9, 1872, p. 50).

CYTHERIDÆ.

Cythere Müller, 1785; Entomostraca, etc., p. 64.
Xestoleberis Sars, 1865; Öfversigt af Norges Marine Ostracoder, p. 68.
Bythocythere Sars, 1865; Öfversigt af Norges Marine Ostracoder.
Carbonia Jones, 1870; Geol. Mag., vol. 7, p. 218.
Youngia Jones and Kirkby, 1886; Quart. Jour. Geol. Soc. London, vol. 42, p. 507.
Thlipeura Jones and Holl, 1869; Annals Mag. Nat. Hist., London, 4th series, vol. 3, p. 213.
Bursulella Jones, 1887; Notes on some Sil. Ostracoda from Gothland, p. 7.
Aristozoe Barrande, 1872; Syst. Sil. Bohême, vol. 1, suppl., p. 474.
Orozoe Barrande, 1872; Syst. Sil. Bohême, vol. 1, suppl., p. 537.
Callizoe Barrande, 1872; Syst. Sil. Bohême, vol. 1, suppl., p. 503.
Zonozoe Barrande, 1872; Syst. Sil. Bohême, vol. 1, suppl., p. 554.
Hippa Barrande, 1872; Syst. Sil. Bohême, vol. 1, suppl., p. 516.
Bolbozoe Barrande, 1872; Syst. Sil. Bohême, vol. 1, suppl., p. 500.
Elpe Barrande, 1872; Syst. Sil. Bohême, vol. 1, suppl., p. 510.
Nothozoe Barrande, 1872; Syst. Sil. Bohême, vol. 1, suppl., p. 536.
Caryon Barrande, 1872; Syst. Sil. Bohême, vol. 1, suppl., p. 505.
Cryptozoe Packard, 1888; Proc. Acad. Nat. Sci. Phila., 1888, p. 381.
Cytheropsis (McCoy) Barrande, 1872; Syst. Sil. Bohême, vol. 1, suppl., p. 508.

CIRRIPEDÆ.

Plumulites Barrande, 1872; Syst. Sil. Bohême, vol. 1, suppl., p. 565.
Strobilepis Clarke, 1888; Palæont. New York, vol. 7, p. 212.
Palæocreusia Clarke, 1888; Palæont. New York, vol. 7, p. 210.
Protobalanus Whitfield, 1888; Palæont. New York, vol. 7, p. lxii; Bull. Am. Mus. Nat. Hist., vol. 2, 1889, p. 66.
Turrilepas Woodward, 1865; Quart. Jour. Geol. Soc. London, vol. 21, p. 489.

DECAPODA.

Anthrapalæmon Salter, 1861; Quart. Jour. Geol. Soc. London, vol. 17, p. 529.
Palæopalæmon Whitfield, 1880; Am. Jour. Sci., 3d series, vol. 19, p. 40.
Crangopsis Salter, 1863; Quart. Jour. Geol. Soc. London, vol. 19, p. 80.
Pseudo-Galathea Peach, 1882; Trans. Royal Soc. Edinb., vol. 30, p. 573.

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SCHIZOPODA.

Gampsonyx Meyer, 1847; Verhandl. Nat. Vereins Preuss., vol. 4, p. 86.
Palæocaris Meek and Worthen, 1865; Proc. Acad. Nat. Sci. Phila., p. 48.
Nectotelson Brocchi, 1880; Bull. Soc. Géol. France, 3d series, vol. 8, p. 10.

AMPHIPODA.

Diplostylus Salter, 1863; Quart. Jour. Geol. Soc. London, vol. 19, p. 76.

STROMAPODA.

Amphipeltis Salter, 1863; Quart. Jour. Geol. Soc. London, vol. 19, p. 75.

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CATALOGUE OF NORTH AMERICAN PALEOZOIC CRUSTACEA—NON-TRILOBITA.

(Current generic names in bold face; synonyms in *Italic.*]

Acanthotelson Meek and Worthen, 1865; Proc. Acad. Nat. Sci. Phila., vol. 17, p. 46; Geol. Survey Illinois, vol. 2, 1866, p. 299.
Type, *A. stimsoni.*
—— **eveni** Meek and Worthen, 1868; Am. Jour. Sci., 2d series, vol. 46, p. 28. Coal Measures.
—— **eveni** Meek and Worthen, 1868; Geol. Survey Illinois, vol. 3, p. 551, figs. a–d.
—— **eveni** White, 1884; 13th Rept. Dept. Geol. Nat. Hist. Indiana, p. 177, pl. 38, figs. 4–7.
—— **eveni** Packard, 1886; Mem. Nat. Acad. Sci., vol. 3, p. 125.
—— *inequalis.* (See **Palæocaris typus.**)
—— ? **magister** Packard, 1886; Mem. Nat. Acad. Sci., vol. 3, p. 127, pl. 1, fig. 2; pl. 2, figs. 4, 5. Carboniferous.
—— **stimpsoni** Meek and Worthen, 1865; Proc. Acad. Nat. Sci. Phila., vol. 17, p. 47. Coal Measures.
—— **stimpsoni** Meek and Worthen, 1866; Geol. Survey Illinois, vol. 2, p. 401, pl. 32, figs. 6, 6 a–f.
—— **stimpsoni** Meek and Worthen, 1868; Geol. Survey Illinois, vol. 3, p. 549, figs. a, b.
—— **stimpsoni** Woodward, 1881; Geol. Mag., decade 2, vol. 8, p. 533, pl. 14, fig. 4.
—— **stimpsoni** White, 1884; 13th Rept. Dept. Geol. Nat. Hist. Indiana, p. 176, pl. 37, figs. 4, 5.
—— **stimpsoni** Packard, 1886; Mem. Nat. Acad. Sci., vol. 3, p. 124.
Packard considers this species to be the young of *Acanthotelson eveni.*
Æchmina Jones and Holl, 1887; Annals Mag. Nat. Hist., 5th series, vol. 3, p. 217.
—— **byrnesi** (Miller) Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 12, pl. 3, figs. 9–11. Cincinnati.
For other references, see *Leperditia byrnesi* Miller.
—— **spinosa** (Hall) Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 11, pl. 3, figs. 4–8. Niagara.
For other references, see *Cytherina spinosa* Hall.
Amphipeltis Salter, 1863; Quart. Jour. Geol. Soc. London, vol. 19, p. 75.
—— **paradoxus** Salter, 1863; Quart. Jour. Geol. Soc. London, vol. 19, p. 76, figs. 11 a, b. Devonian.
—— **paradoxus** Dawson, 1868; Acadian Geology, p. 523, fig. 180.
—— **paradoxus** Salter and Woodward; Chart of Fossil Crustacea, pl. 3, fig. 3.
Anthraconetes Meek and Worthen, 1868; Am. Jour. Sci., 2d series, vol. 46, p. 21.
—— *mazonensis* Meek and Worthen. (See **Eurypterus mazonensis.**)
Anthrapalæmon Salter, 1861; Quart. Jour. Geol. Soc. London, vol. 17, p. 529.
Type, *A. grossarti* Salter.
—— **gracilis** Meek and Worthen, 1865; Proc. Acad. Nat. Sci. Phila., vol. 17, p. 50. Coal Measures.
—— **gracilis** Meek and Worthen, 1866; Geol. Survey Illinois, vol. 2, p. 407, pl. 32, figs. 4 a, b, c.

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Anthrapalæmon gracilis Meek and Worthen, 1868; Geol. Survey Illinois, vol. 3, p. 554, figs. a, b.

—— **gracilis** White, 1884; 13th Rept. Dept. Geol. Nat. Hist. Indiana, p. 180, pl. 38, figs. 8, 9.

—— **gracilis** Packard, 1885; American Naturalist, vol. 19, p. 880.

—— **gracilis** Packard, 1886; Mem. Nat. Acad. Sci., vol. 3, p. 135, pl. 4, figs. 1, 2, 3, 5, 6; pl. 7, figs. 3–6.

—— [*Palæocarabus*] **hillianus** Dawson, 1878; Geol. Mag., vol. 4, p. 56, fig. 1. Coal Measures.

—— [*Palæocarabus*] **hillianus** Dawson, 1878; Suppl. Acadian Geology, p. 55, fig. 10.

Aparchites Jones, 1889; Annals Mag. Nat. Hist., 6th series, vol. 3, p. 385.

—— **minutissimus** (Hall) Ulrich, 1889; Contributions Micro-Palæont., pt. 2, p. 49. For other references, see *Leperditia* [*Isochilina*] *minutissima* Hall. Hudson.

—— **unicornis** Ulrich, 1889; Contributions Micro-Palæont., pt. 2, p. 50, pl. 9, fig. 11. For other references, see *Leperditia unicornis*. Hudson.

Aptychopsis Barrande, 1872; Syst. Sil. Bohême, vol. 1, suppl., p. 436.

Archæocaris Meek, 1871; Proc. Acad. Nat. Sci. Phila., vol. 23, p. 335.

—— **vermiformis** Meek, 1871; Proc. Acad. Nat. Sci. Phila., vol. 23, p. 335. Carboniferous.

Aristozoe Barrande, 1872; Syst. Sil. Bohême, suppl., vol. 1, p. 474.

—— **rotundata** Walcott, 1887; Am. Jour. Sci., 3d series, vol. 34, p. 193, pl. 1, fig. 9. Cambrian.

—— **troyensis** (Ford) Walcott, 1887; Am. Jour. Sci., 3d series, vol. 34, p. 193, pl. fig. 8. Cambrian.

—— [*Leperditia*] **troyensis** Ford, 1873; Am. Jour. Sci., 3d series, vol. 6, p. 138.

Aristozoe sp. Shaler and Foerste, 1888; Bull. Mus. Comp. Zoology, vol. 16, p. 35, pl. 2, fig. 18. Cambrian.

Belinurus Koenig, 1820; Icones. Foss. Sectiles, p. 18, fig. 230; Baily, Annals Mag. Nat. Hist., London, 3d series, vol. 11, 1863.

—— *danæ* Meek and Worthen. (See **Prestwichia danæ**.)

—— **lacoei** Packard, 1885; American Naturalist, vol. 19, p. 292. Carboniferous.

—— **lacoei** Packard, 1886; Mem. Nat. Acad. Sci., vol. 3, p. 149, pl. 5, fig. 5.

Beyrichia McCoy, 1846; Silurian Foss. Ireland, p. 58.
Type, *Beyrichia klodeni* McCoy.

—— **æquilatera** Hall, 1860; Canadian Naturalist, vol. 5, p. 158, fig. 20. Silurian.

—— **æquilatera** Dawson, 1868; Acadian Geology, p. 609, fig. 217.

—— **æquilatera** Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 18, pl. 2, fig. 6.

—— **atlantica** Billings, 1865; Pal. Foss., vol. 1, p. 300. Quebec.

—— **bela** Walcott, 1883; Description New Species Trenton Group, p. 7, pl. 17, figs. 11, 11 a. Trenton.

—— **bela** Walcott, 1884; 35th Rept. New York State Mus. Nat. Hist., p. 213, pl. 17, figs. 11, 11 a.

—— **buchiana?** Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 16, pl. 3, fig. 25. Cincinnati.

—— **chambersi** Miller, 1874; Cincinnati Quart. Jour. Sci., vol. 1, p. 234, fig. 27. Hudson.

—— **chambersi** Hall and Whitfield, 1875; Pal. Ohio, vol. 2, p. 104, pl. 4, figs. 11, 12.

—— **ciliata** Emmons, 1855; American Geology, pt. 2, p. 219, fig. 74 c. Hudson.

—— **ciliata** Miller, 1875; Cincinnati Quart. Jour. Sci., vol. 2, p. 351.

—— **ciliata** Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 19, pl. 3, figs. 12–16; pl. 4, figs. 16–18.
Syn., *Beyrichia tumifrons* Hall.

—— **cincinnatiensis** Miller, 1875; Cincinnnati Quart. Jour. Sci., vol. 2, p. 350, fig. 25. Hudson.

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Beyrichia cincinnatiensis Walcott, 1876; Trans. Albany Inst., vol. 10, p. 23.
—— **clarkei** Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 17, wood-cut, fig. 2. Lower Helderberg.
—— **clathrata** Jones, 1858; Annals Mag. Nat. Hist., London, 3d series, vol. 1, p. 242, pl. 9, fig. 1. Niagara.
—— **dagon** Clarke, 1885; Bull. U. S. Geol. Survey, No. 16, p. 29, pl. 2, figs. 6, 7. Genesee.
—— **decora** Billings, 1866; Catalogue Sil. Foss. Anticosti, p. 67.
—— **duryi** Miller, 1874; Cincinnati Quart. Jour. Sci., vol. 1, p. 232, figs. 24, 25. Hudson.
—— **fœtoidea** White and St. John, 1868; Trans. Chicago Acad. Sci., vol. 1, p. 126, figs. 11 a, b. Niagara.
—— **granulosa** Hall, 1876; 28th Rept. New York State Mus. Nat. Hist., Doc. Ed. Expl., pl. 32, fig. 4. Niagara.
—— **granulosa** Hall, 1876; 28th Rept. New York State Mus. Nat. Hist., p. 186, pl. 32, fig. 4.
—— **granulosa** Hall, 1883; 11th Annual Rept. Dept. Geol. Nat. Hist. Indiana, p. 331, pl. 34, fig. 4.
—— **granulosa** Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 15, pl. 1, fig. 3.
—— **granulata** Hall, 1859; Pal. New York, vol. 3, p. 377, pl. 79 b, figs. 1 a–d. Lower Helderberg.
—— **halli** Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 15, pl. 4, fig. 21. Waterlime.
—— **hamiltonensis** Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 19, pl. 2, fig. 3. Hamilton.
—— **jonesii** Dawson, 1868; Acadian Geology, p. 313, fig. 132. Carboniferous.
—— *lata.* (See **Bollia lata** Vanuxem.)
—— *lithofactor* White and St. John, Prelim. Notice New Genera and Species Foss., May 8, 1867, p. 2.
Changed to **Beyrichia petrifactor**, which see. Coal Measures.
—— *lithofactor* var. *velata; idem.*, p. 2. (See **Beyrichia petrifactor** var. **velata**.)
—— **logani** Jones, 1858; Annals Mag. Nat. Hist., London, 3d series, vol. 1, p. 244, pl. 9, figs. 6–10. Chazy.
—— **logani** Jones, 1858; Geol. Survey Canada, decade 3, p. 91, pl. 11, figs. 1–5.
—— **logani** var. **remiformis** Jones, 1858; Geol. Survey Canada, decade 3, p. 91, pl. 11, fig. 1.
—— **logani** var. **leperditoides** Jones, 1858; Geol. Survey Canada, decade 3, p. 91, pl. 11, fig. 5.
—— **maccoyana** Jones, 1855; Annals Mag. Nat. Hist., London, 2d series, vol. 16, p. 88, pl. 5, fig. 14. Onondaga.
—— **maccoyana** Jones, 1858; Annals Mag. Nat. Hist., London, 3d series, vol. 1, p. 252, pl. 10, fig. 15.
—— **maccoyana** Jones, 1858; Geol. Survey Penn., vol. 2, p. 834, fig. 695.
—— *notata.* (See **Kloedenia notata** (Hall) Jones.)
—— **nova scotica** Jones and Kirkby, 1884; Geol. Mag., 5th series, vol. 1, p. 337, pl. 12, figs. 5, 6. Carboniferous.
—— **sp?** Dawson, 1868; Acadian Geology, p. 256, fig. 78 c.
—— [*Primitia*] **occidentalis** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 104, pl. 17, figs. 4, 4 a. Devonian.
—— **oculifera** Hall, 1871; Pamphlet Cincinnati Group, p. 8. Hudson.
—— **oculifera** Hall, 1872; 24th Rept. New York State Mus. Nat. Hist., p. 232, pl. 8, figs. 9, 10.
—— **oculifera** Hall and Whitfield, 1875; Pal. Ohio, vol. 2, p. 103, pl. 4, figs. 9, 10.
—— **oculifera** Miller, 1874; Cincinnati Quart. Jour. Sci., vol. 1, p. 118.
oculifera Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 21, pl. 4, figs. 19 a, b, 20.

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Beyrichia oculina Hall, 1859; Pal. New York, vol. 3, p. 378, pl. 79 b, figs. 2 a–e. Lower Helderberg.

—— **oculina** Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 16, pl. 1, fig. 4.

—— **parasitica** (Hall) Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 16, wood-cut. For other references, see *Leperditia parasitica*.

—— **pennsylvanica** Jones, 1858; Annals Mag. Nat. Hist., London, 3d series, vol. 1, p. 253, pl. 10, fig. 16–18. Onondaga.

—— **pennsylvanica** Jones, 1858; Geol. Survey Penn., vol. 2, p. 834, fig. 696.

—— **persulcata** Ulrich, 1879; Jour. Cincinnati Soc. Nat. Hist., vol. 2, p. 12, pl. 7, fig. 6. Hudson.

—— **petrifactor** White and St. John; Trans. Chicago Acad. Sci., vol. 1, p. 125.

—— **petrifactor** var. **velata**; *idem.*, p. 126.

—— **plagosa** Jones, 1858; Annals Mag. Nat. Hist., London, 3d series, vol. 1, p. 243, pl. 9, fig. 2. Niagara.

—— **punctulifera** Hall, 1861; Des. New Species Fossils, p. 83. Hamilton.

—— **punctulifera** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 111.

—— **pustulosa** Hall, 1860; Canadian Naturalist, vol. 5, p. 157, fig. 19. Silurian.

—— **pustulosa** Dawson, 1868; Acadian Geology, p. 608, fig. 216.

—— **pustulosa** Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 18, pl. 2, fig. 1 a–c. Referred to *Beyrichia tuberculata* Boll var. *pustulosa* Hall.

—— *quadrilirata* Hall and Whitfield, 1875; Pal. Ohio, vol. 2, p. 105, pl. 4, figs. 6, 7. Hudson.

—— *quadrilirata* Miller, 1875; Cincinnati Quart. Jour. Sci., vol. 2, p. 351. (See **Strepula quadrilirata.**)

—— **regularis** Emmons, 1855; American Geology, pt. 2, p. 219, fig. 74 b. Hudson.

—— **regularis** Miller, 1875; Cincinnati Quart. Jour. Sci., vol. 2, p. 351.
This species is placed as a synonym to *Bollia lata* by Jones (1890, Quart. Jour. Geol. Soc., vol. 46, p. 13).

—— **remiformis** Jones, 1858; Geol. Survey Canada, decade 3, p. 91, pl. 11, fig. 1. Chazy.

—— **richardsoni** Miller, 1874; Cincinnati Quart. Jour. Sci., vol. 1, p. 347, fig. 40. Hudson.

—— **rugulifera** Jones, 1858; Annals Mag. Nat. Hist. London, 3d series, vol. 1, p. 242, pl. 9, fig. 4. Niagara.

—— **sigillata** Jones, 1858; Annals Mag. Nat. Hist., London, vol. 1, p. 242, pl. 9, fig. 5. Niagara.

—— **simplex** (Jones) Emmons, 1855; American Geology, vol. 1, pt. 2, p. 218, fig. 74 a.

—— [*Cytherina*] **spinosa** Hall, 1852; Pal. New York, vol. 2, p. 317, pl. 67, figs. 17–20. (See **Æchmina spinosa.**) Niagara.

—— *striato-marginatus* Miller, 1874; Cincinnati Quart. Jour. Sci., vol. 1, p. 233, fig. 26.
This species is referred to a new genus. (See **Eurychilinda striatomarginatus.**) Hudson.

—— *symmetrica* Hall, 1852; Pal. New York, vol. 2, p. 317, pl. 67, fig. 16. (See **Bollia symmetrica.**) Niagara.

—— **trisulcata** Hall, 1859; Pal. New York, vol. 3, p. 381, pl. 79, figs. 5 a, b. Lower Helderberg.

—— **trisulcata** Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 14, pl. 1, fig. 2.

—— **tumifrons** Hall, 1871; Des. New Species Foss. Hudson River Group, p. 7. Hudson.

—— **tumifrons** Hall, 1872; 24th Rept. New York State Mus. Nat. Hist., p. 231, pl. 8, fig. 11.

—— **tumifrons** Hall and Whitfield, 1875; Pal. Ohio, vol. 2, p. 102, pl. 4, fig. 8.

—— **tumifrons** Miller, 1874; Cincinnati Quart. Jour. Sci., vol. 1, p. 119.
This species is classed by Jones 1890, Quart. Jour. Geol. Soc., vol. 46, p. 19, as synonymous to *Beyrichia ciliata* Emmons.

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Beyrichia venusta Billings, 1866; Catalogue Silurian Fossils Anticosti, p. 68.
Bollia Jones and Holl, 1886; Annals Mag. Nat. Hist., 5th series, London, vol. 17, p. 360.
—— [*Agnostus*] **latus** Vanuxem, 1842; Geol. New York, 3d Geol. Dist., p. 80. Clinton.
—— [*Beyrichia*] **lata** Hall, 1852; Pal. New York, vol. 2, p. 301, pl. A 66, figs. 10 a–c.
—— [*Beyrichia*] **lata** Jones, 1858; Notes on Palæozic Entomostraca, No. 2, p. 168, pl. 6, fig. 13.
—— **lata** Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 12, pl. 3, figs. 1–3.
—— [*Beyrichia*] **symmetrica** Hall, 1852; Pal. New York, vol. 2, p. 317, pl. 67, fig. 16. Niagara.
—— **symmetrica** Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 12.
This species is closely allied to *Bollia lata*.
—— **ungula** (Claypole MS.) Jones, 1889; American Geologist, vol. 4, p. 338, pl. fig. 10–13. Marcellus.
Bythocypris Brady, 1880; Challenger Exped., Rep. Ostracoda, p. 45.
—— **cylindrica** (Hall) Ulrich, 1889; Contributions Micro-Palæont., pt. 2, p. 48, pl. 9, fig. 6. Trenton and Hudson.
For other references, see *Leperditia* [*Isochilina*] *cylindrica* Hall.
—— **favulosa** Jones, 1889; American Geologist, vol. 4, p. 338, pl. figs. 2 a–c. Marcellus.
—— **oviformis** Jones, 1889; American Geologist, vol. 4, p. 340, pl. figs. 3 a–c. Lower Helderberg.
Carbonia Jones and Kirkby, 1879; Annals Mag. Nat. Hist., London, 5th series, vol. 4, p. 28.
—— ? **bairdioides** (?) Jones and Kirkby, 1884; Geol. Mag., 5th series, vol. 1, p. 358, pl. 12, figs. 8 a–d. Carboniferous.
Syn., *Bairdia* sp. ? Dawson, 1868; Acadian Geology, p. 206, figs. 48 a (?).
—— [*Cythere?* (*Carbonia*)] **bairdiodes** Jones and Kirby, 1879; Annals Mag. Nat. Hist., London, 5th series, vol. 4, p. 38, pl. 3, figs. 24, 25.
—— ? **bairdioides**? Jones and Kirkby, 1884; Geol. Mag., decade 3, p. 358, pl. 12, figs. 8 a–d.
—— ? **elongata** Jones and Kirkby, 1884; Annals Mag. Nat. Hist., London, 6th series, vol. 1, p. 361, pl. 12, fig. 10. Carboniferous.
—— ? **elongata** Jones and Kirkby, 1884; Geol. Mag., decade 3, p. 361, pl. 12, fig. 10.
—— **fabulina** Jones and Kirkby, 1879; Annals Mag. Nat. Hist., London, 5th series, vol. 4, p. 31, pl. 2, figs. 1–9.
—— **fabulina** var. **humilis** Jones and Kirkby, 1879; Annals Mag. Nat. Hist., London, 5th series, vol. 4, p. 31, pl. 2, figs. 11–14.
—— **fabulina** Jones, 1889; Geol. Mag., decade 3, vol. 6, p. 270, figs. 1–4.
—— [*Cytherilla*] *inflata* Dawson, 1868; Acadian Geology, p. 206, fig. 48 b.
—— **fabulina** Jones and Kirkby, 1884; Geol. Mag., decade 3, vol. 1, p. 358, pl. 12, figs. 9 a–e.
Ceratiocaris McCoy, 1849; Annals Mag. Nat. Hist., London, vol. 4, p. 412.
—— **aculeatus** Hall, 1859; Pal. New York, vol. 3, p. 422*, pl. 80 a, fig. 10. Waterlime.
—— **acuminatus** Hall, 1859; Pal. New York, vol. 3, p. 422*, pl. 84, fig. 6. Waterlime.
—— **acuminatus** Pohlman, 1886; Bull. Buffalo Soc. Nat. Sci., vol. 5, p. 28, pl. 3, fig. 2.
—— *armatus* Hall. (See **Echinocaris punctata.**)
—— **beecheri** Clarke, 1881; Bull. U. S. Geol. Survey, No. 16, p. 44, pl. 2, fig. 1. Devonian.
—— **beecheri** Hall, 1888; Pal. New York, vol. 7, p. 104, pl. 31, fig. 3.
—— [*Colpocaris*] **bradleyi** Meek, 1871; Proc. Acad. Nat. Sci. Phila., vol. 23, p. 332. Lower Carboniferous.
—— [*Onchus*] **deweyi** Hall, 1852; Pal. New York, vol. 2, p. 320, pl. 71, figs. 1 a–d. Niagara.

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Ceratiocaris [*Colpocaris*] **etytroides** Meek, 1871; Proc. Acad. Nat. Sci. Phila., vol. 23, p. 334. Lower Carboniferous.

—— **grandis** Pohlman, 1881; Bull. Buffalo Soc. Nat. Sci., vol. 4, p. 19, fig. 5. Waterlime.

—— **longicaudus** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 70, pl. 1, fig. 7 (*not* figs. 4, 5, 6). Hamilton.

—— **longicaudus** Packard, 1883; 12th Annual Rept. U. S. Geol. Survey Territories, p. 450.

—— **longicaudus** Jones and Woodward, 1884; Geol. Mag., decade 3, vol. 1, p. 1.

—— **longicaudus** Etheridge, Woodward, and Jones; 3d Rept. Comm. Foss. Phyllopoda, p. 35.

—— **longicaudus** Hall, 1888; Pal. New York, vol. 7, p. 163, pl. 31, fig. 1.
Not *C. longicaudus* Clarke, 1885; Bull. U. S. Geol. Survey, No. 16, p. 20.

—— **macooyana** Hall, 1859; Pal. New York, vol. 3, p. 421, pl. 84, figs. 1–5. Waterlime.

—— ? *punctatus* Hall. (See **Echinocaris punctata.**)

—— **simplex** Clarke, 1885; Bull. U. S. Geol. Survey, No. 16, p. 43, pl. 2, fig. 2. Devonian.

—— ? **simplex** Hall, 1888; Pal. New York, vol. 7, p. 165, pl. 31, fig. 2.

—— ? **sinuata** Meek and Worthen, 1868; Am. Jour. Sci., 2d series, vol. 46, p. 22. Coal Measures.

—— ? **sinuata** Meek and Worthen, 1868; Geol. Survey Illinois, vol. 3, p. 540, fig. a.

—— [*Solenocaris*] **strigata**, Meek, 1871; Proc. Acad. Nat. Sci. Phila., vol. 23, p. 335. Lower Carboniferous.

—— [*Solenocaris*] **strigata** Meek, 1875; Pal. Ohio, vol. 2, p. 321, pl. 18, figs. 4 a–c.
The generic name of *Solenocaris* was used by Mr. J. Young for a genus of the Paleozoic Crustacea in 1868. See **Strigocaris.**

Crangopsis Salter, 1863; Name changed from *Palæocrangon.*

Cryptozoe Packard, 1886; Proc. Am. Philos. Soc., vol. 23, p. 381.

—— **problematicus** Packard, 1886; Proc. Am. Philos. Soc., vol. 23, p. 382, fig. 3, plate. Carboniferous.

Cyclus De Koninck, 1841; Mém. Acad. Sci. Bruxelles, vol. 14, p. 18.

—— **americana** Packard, 1885; American Naturalist, vol. 19, p. 293. Coal Measures.

—— **americana** Packard, 1886; Mem. Nat. Acad. Sci., vol. 3, p. 143, pl. 5, figs. 1, 1 a; pl. 6, figs. 4, 4 a.

Cythere Müller, 1785; Entomostraca, p. 64.

—— [*Beyrichia*] **americana** Shumard, 1858; Trans. Acad. Sci. St. Louis, vol. 1, p. 227. Upper Coal Measures.

—— *carbonaria* Hall. (See **Leperditia carbonaria.**)

—— *cincinnatiensis* Meek. (See **Entomis cincinnatiensis.**)

—— **crassimarginata** Winchell, 1862; Proc. Acad. Nat. Sci. Phila., p. 429. Marshall.

—— **irregularis** Miller, 1878; Jour. Cincinnati Soc. Nat. Hist., vol. 1, p. 106, pl. 3, figs. 7, 7 a. Hudson.

—— **nebrascensis** Geinitz, 1866; Carb. und Dyas in Nebraska, p. 2, pl. 1, fig. 2. Coal Measures.

—— **nebrascensis** Meek, 1872; Rept. U. S. Geol. Survey Territories, Final Report Nebraska, p. 237, pl. 11, figs. 1, 2, 3 a, b (?).

—— **nebrascensis** Keyes, 1888; Proc. Acad. Nat. Sci. Phila., p. 222.

—— **ohiones** Herrick, 1889; Bull. Den. Univ., vol. 4, p. 60, pl. 8, fig. 8; vol. 3, pl. 3, fig. 19. Kinderhook.

—— **ohiones** Herrick, 1890; American Geologist, vol. 4, p. 254.

—— *okeni.* (See **Leperditia okeni.**)

—— **simplex** White and St. John, 1867; Prelim. Notice New Species Foss., p. 3. St. Louis.

—— **simplex** White and St. John, 1868; Trans. Chicago Acad. Sci., vol. 1, p. 127,

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Cythere sp.? Dawson, 1868; Acadian Geology, p. 256, fig. 78 a. Carboniferous.
—— *sublævis.* (See **Leperditia sublævis.**)
—— *subrecta.* (See **Leperditia subrecta.**)
Cytherina Lamarck, 1818; Animaux sans Vert., vol. 5, p. 125.
—— *alta.* (See **Leperditia alta.**)
—— **crenulata** Emmons, 1855; Am. Geology, vol. 1, p. 221, figs. 75 a–d. Trenton.
—— *cylindrica.* (See **Isochilina cylindrica.**)
—— **emmonsi** Vogdes, 1889; Annals N. Y. Acad. Sci., vol. 5, p. 13, to replace *C. subcylindrica.*
—— *spinosa.* (See **Beyrichia spinosa.**)
—— *subcylindrica* Emmons, 1855; Am. Geology, vol. 1, p. 220, fig. 75 b. Trenton.
This name was used by Münster for a species of this genus. Change to *C. emmonsi.*
—— **subelliptica** Emmons, 1855; Am. Geology, vol. 1, p. 220, figs. 75 a. Trenton.
Cytherellina Jones and Holl, 1869; Annals Mag. Nat. Hist., London, 4th series, vol. 3, p. 215.
—— **grandella** Whitfield, 1882; Bull. Am. Mus. Nat. Hist. New York, vol. 1, p. 94, pl. 9, figs. 28, 29. Warsaw.
Cytheropsis McCoy, 1855; Synopsis Classification Brit. Pal. Rocks, pl. 1 L., fig. 2.
No definite descriptign of the genus given.
—— *concinna* Jones. (See **Primitia concinna.**)
—— *rugosa* Jones. (See **Primitia rugosa.**)
—— **silique** Jones, 1858; Annals Mag. Nat. Hist., 3d series, London, vol. 1, p. 249, pl. 10, fig. 6. Trenton.
—— **silique** Jones, 1858; Geol. Survey Canada, decade 3, p. 99.
—— **silique** Jones, 1869; Annals Mag. Nat. Hist., London, 4th series, vol. 3, p. 216, pl. 14, figs. 1–6.
Dipeltis Packard, 1885; Am. Naturalist, vol. 19, p. 293.
—— **diplodiscus** Packard, 1885; Am. Naturalist, vol. 19, p. 293. Carboniferous.
—— **diplodiscus** Packard, 1886; Mem. Nat. Acad. Sci., vol. 3, p. 145, pl. 5, figs. 2, 2 a.
Diplostylus Salter, 1863; Quart. Jour. Geol. Soc. London, vol. 19, p. 76.
—— **dawsoni** Salter, 1863; Quart. Jour. Geol. Soc. London, vol. 19, p. 77, fig. 6. Coal Measures.
Dipterocaris Clarke, 1883; Am. Jour. Sci., 3d series, vol. 25, p. 121.
—— **pennæ-dædali** Clarke, 1883; Am. Jour. Sci., 3d series, vol. 25, p. 122, fig. 1. Chemung.
—— **pennæ-dædali** Jones and Woodward, 1884; Geol. Mag., decade 3, vol. 1, p. 349.
—— **pennæ-dædali** Etheridge, Woodward, and Jones, 1884; 2d Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 11.
—— **pennæ-dædali** Etheridge, Woodward, and Jones, 1885; 3d Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 3.
—— **pennæ-dædali** Hall, 1888; Pal. New York, vol. 7, p. 200, pl. 35, fig. 24.
—— **pennæ-dædali** Etheridge, Woodward, and Jones, 1888; 6th Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 9.
—— **percervæ** Clarke, 1883; Am. Jour. Sci., 3d series, vol. 25, p. 123, figs. 4, 5. Chemung.
—— **percervæ** Jones and Woodward, 1884; Geol. Mag., decade 3, vol. 1, p. 349.
—— **percervæ** Etheridge, Woodward, and Jones, 1884; 2d Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 11.
—— **percervæ** Etheridge, Woodward, and Jones, 1885; 3d Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 3.
—— **percervæ** Hall, 1888; Pal. New York, vol. 7, p. 202, pl. 35, figs. 20, 21.
—— **percervæ** Etheridge, Woodward, and Jones, 1888; 6th Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 9.

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Dipterocaris prœne Clarke, 1883; Am. Jour. Sci., 3d series, vol. 25, p. 122, figs. 2, 3. Chemung.

—— **prœne** Jones and Woodward, 1884; Geol. Mag., decade 3, vol. 1, p. 349.

—— **prœne** Etheridge, Woodward, and Jones, 1884; 2d Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 11.

—— **prœne** Etheridge, Woodward, and Jones, 1885; 3d Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 3.

—— **prœne** Hall, 1888; Pal. New York, vol. 7, p. 201, pl. 35, figs. 25–27.

—— **prœne** Etheridge, Woodward, and Jones, 1888; 6th Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 9.

Dithyrocaris (Scouler, 1843, MS.) Portlock, 1843; Rept. Geol. Londonderry, etc., p. 313.

—— **belli** Woodward, 1870; Geol. Mag., decade 2, vol. 8, p. 106, pl. 3, figures. Devonian.

—— **belli** Etheridge, Woodward, and Jones, 1887; 5th Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 6.

—— **belli** Hall, 1888; Pal. New York, vol. 7, p. 194.

—— **carbonaria** Meek and Worthen, 1870; Proc. Acad. Nat. Sci. Phila., vol. 22, p. 55. Coal Measures.

—— **carbonaria** Meek and Worthen, 1873; Geol. Survey Illinois, vol. 5, p. 618, pl. 32, fig. 1.

—— **carbonaria** White, 1884; 13th Rept. Dept. Geol. Nat. Hist. Indiana, p. 178, pl. 39, fig. 2.

—— ***neptuni*** Hall. (See **Mesothyra neptuni.**)

Dolichocephala Claypole, 1883; Proc. Am. Philos. Soc., vol. 21, p. 236.

—— *locoana idem;* p. 236, plate. (See **Stylonurus excelsior.**)

Dolichopterus (subgenus **Eurypterus**) Hall, 1859; Pal. New York, vol. 3, p. 414.*

—— **macrocheous** Hall, 1859; Pal. New York, vol. 3, p. 414,* pl. 83, fig. 1; pl. 83 a, fig. 1. Waterlime.

Echinocaris Whitfield, 1880; Am. Jour. Sci., 3d series, vol. 19, p. 34.

—— **condylepsis** Hall, 1888; Pal. New York, vol. 7, p. 173, pl. 19, figs. 14–17. Chemung.

—— **multinodosa** Whitfield, 1880; Am. Jour. Sci., 3d series, vol. 19, p. 38, fig. 8. (Plates with author's special edition only.) Erie Shales.

—— **multinodosa** Packard, 1882; Am. Naturalist, vol. 16, p. 952, fig. 10.

—— **multinodosa** Packard, 1883; 12th Rept. U. S. Geol. Survey Territories, p. 451, fig. 71 a.

—— **multinodosa** Beecher, 1884; 2d Geol. Survey Penn., vol. PPP, p. 5.

—— **multinodosa** Etheridge, Woodward, and Jones, 1885; 3d Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 35.

—— **multinodosa** Hall, 1888; Pal. New York, vol. 7, p. 180, pl. 29, figs. 18–19.

—— **multinodosa** Etheridge, Woodward, and Jones, 1888; 6th Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 8.

—— [*Ceratiocaris*] **punctatus** Hall, 1863; 16th Rept. New York State Cab. Nat. Hist. p. 74, pl. 1, fig. 8. Hamilton.

—— **punctatus** Whitfield, 1880; Am. Jour. Sci., 3d series, vol. 19, p. 39.

Syn., *Ceratiocaris armatus* Hall, 1863; 16th Rept. New York State Cab. Nat. Hist., p. 72, pl. 1, figs. 1–3.

Ceratiocaris armatus Hall, 1876; Illus. Devonian Foss., pl. 23, figs. 4, 5.

—— [*Ceratiocaris* (*Aristozoe*)] **punctatus** Hall, 1876; Illus. Devonian Foss., Expl. pl. 23, fig. 7.

—— **punctatus** Packard, 1882; Am. Naturalist, vol. 16, p. 952, fig. 12.

—— **punctatus** Packard, 1883; 12th Rept. U. S. Geol. Survey Territories, p. 450, fig. 70.

Syn., *armatus* Packard, 1883; 12th Rept. U. S. Geol. Survey Territories, p. 451.

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Echinocaris punctatus Beecher, 1884; 2d Geol. Survey Penn., vol. PPP, p. 6, pl. 1, figs. 13–16; also fig. 1 in text, page 4.

Syn., *armatus* Jones and Woodward, 1884; Geol. Mag., decade 3, vol. 1, p. 2, pl. 13, fig. 2.

armatus Etheridge, Woodward, and Jones, 1885; 3d Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 35.

—— **punctatus** Hall, 1888; Pal. New York, vol. 7, p. 166, pl. 27, fig. 10; pl. 28, fig. 1–7; pl. 29, fig. 1–8.

—— **punctatus** Etheridge, Woodward, and Jones, 1888; 6th Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 8.

—— **pustulosa** Whitfield, 1880; Am. Jour. Sci., 3d series, vol. 19, p. 38, pl. fig. 7 (plate with author's special edition only). Erie Shales.

—— **pustulosa** Packard, 1883; 12th Rept. U. S. Geol. Survey Territories, p. 451.

—— **pustulosa** Beecher, 1884; 2d Geol. Survey Penn., vol. PPP., p. 5.

—— **pustulosa** Jones and Woodward, 1884; Geol. Mag., decade 3, vol. 1, p. 2, pl. 13, fig. 6.

—— **pustulosa** Etheridge, Woodward, and Jones, 1885; 3d Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 35.

—— **pustulosa** Hall, 1888; Pal. New York, vol. 7, p. 178, pl. 29, figs. 9, 10.

—— **pustulosa** Etheridge, Woodward, and Jones, 1888; 6th Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 8.

—— **socialis** Beecher, 1884; 2d Geol. Survey Penn., vol. PPP, p. 10, pl. 1, figs. 1–1*e*. Chemung.

—— **socialis** Etheridge, Woodward, and Jones, 1885; 3d Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 35.

—— **socialis** Hall, 1888; Pal. New York, vol. 7, p. 174, pl. 30, figs. 1–12.

—— **socialis** Etheridge, Woodward, and Jones, 1888; 6th Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 8.

—— **sublevis** Whitfield, 1880; Am. Jour. Sci., 3d series, vol. 19, p. 36, pl. figs. 4–6 (plate with the author's special edition only). Erie Shales.

—— **sublevis** Packard, 1882; Am. Naturalist, vol. 16, p. 952, fig. 11.

—— **sublævis** Packard, 1883; 12th Rept. U. S. Geol. Survey Territories, p. 450, fig. 71 b.

—— **sublevis** Beecher, 1884; 2d Geol. Survey Penn., vol. PPP, p. 5.

—— **sublævis** Jones and Woodward, 1884; Geol. Mag., decade 3, vol. 1. p. 2, pl. 13, figs. 3, 4, 5.

—— **sublævis** Etheridge, Woodward, and Jones, 1885; 3d Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 35.

—— **sublævis** Hall, 1888; Pal. New York, vol. 7, p. 176, pl. 29, figs. 11–13.

—— **sublævis** Etheridge, Woodward, and Jones, 1888; 6th Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 8.

—— **whitfieldi** Clarke, 1885; Bull. U. S. Geol. Survey, No. 16, p. 45, pl. 2, figs. 3, 4. Portage.

—— **whitfieldi** Hall, 1888; Pal. New York, vol. 7, p. 172, pl. 29, figs. 20, 21.

—— **whitfieldi** Etheridge, Woodward, and Jones, 1888; 6th Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 8.

Echinognathus Walcott, 1882; Am. Jour. Sci., 3d series, vol. 23, p. 213.

—— **clevelandi** Walcott, 1882; Am. Jour. Sci., 3d series, vol. 23, p. 213, figs. 1, 2. Utica.

—— [*Eurypterus ?*] **clevelandi** Walcott, 1882; Am. Jour. Sci., 3d series, vol. 23, p. 151.

Elymocaris Beecher, 1884; 2d Geol. Survey Penn., vol. PPP, p. 13.

—— **siliqua** Beecher, 1884; 2d Geol. Survey Penn., vol. PPP, p. 13, pl. 2, figs. 1, 2. Chemung.

—— **siliqua** Etheridge, Woodward, and Jones, 1885; 3d Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 35.

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Elymocaris siliqua Hall, 1888; Pal. New York, vol. 7, p. 182, pl. 31, figs. 5, 6.

—— **siliqua** Etheridge, Woodward, and Jones, 1888; 6th Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 8.

Entomis Jones, 1861; Mem. Geol. Survey Scotland, Expl. Map 32, p. 137; also, Annals Mag. Nat. Hist., London, 4th series, vol. 11, p. 413.

—— [*Cythere*] **cincinnatiensis** Meek, 1871; Proc. Acad. Nat. Sci. Phila., vol. 23, p. 331. Hudson.

—— [*Cythere*] **cincinnatiensis** Meek, 1873; Pal. Ohio, vol. 1, p. 158, pl. 14, figs. 1 a-1 d.

—— [*Cythere*] **cincinnatiensis** Miller, 1874; Cincinnati Quart. Jour. Sci., vol. 1, p. 120.

—— **cincinnatiensis** Jones, 1884; Annals. Mag. Nat. Hist., London, 5th series, vol. 14, note p. 395.

—— **rhomboidea** Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 10, pl. 2, figs. 9, 10 a, b. Hamilton.

Equisetides wrightiana. This species is referred by Woodward and Jones (3d Report Comm. Foss. Phyllopoda Brit. Assoc., 1885, p. 360) to *Echinocaris*. Prof. James Hall places it provisionally with *Stylonurus*, which see.

Estheria Ruffell, 1857; Mus. Senckenberg, vol. 2, p. 119.

—— **dawsoni** Jones, 1870; Geol. Mag., vol. 7, p. 220, pl. 9, fig. 15. Carboniferous.

—— **dawsoni** Jones, 1878; Geol. Mag., decade 2, vol. 2, p. 101, pl. 3, fig. 2.

—— sp. ? Dawson, 1868; Acadian Geology, p. 256, fig. 78 d.

—— **dawsoni** Jones and Kirkby, 1884; Geol. Mag., decade. 3, vol. 1, p. 361, pl. 12, fig. 12.

—— **pulex** Clarke, 1882; Am. Jour. Sci., 3d series, vol. 23, p. 476, pl., fig. 4. Hamilton.

—— **pulex** Packard, 1883; 12th Rept. U. S. Geol. Survey Territories, p. 355.

—— **pulex** Etheridge, Woodward, and Jones, 1885; 5th Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 10.

—— **pulex** Hall, 1888; Pal. New York, vol. 7, p. 206, pl. 35, figs. 10, 11.

—— **pulex** Etheridge, Woodward, and Jones, 1888; 6th Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 9.

Euproops Meek, 1867; Am. Jour. Sci., 2d series, vol. 34, p. 394. (See **Bellinurus** and **Prestwichia**.)

Eurychilinda Ulrich, 1889; Contributions Micro-Palæont., pt. 2, p. 52.

—— **mantiobensis** Ulrich, 1889; Contributions Micro-Palæont., pt. 2, p. 53, pl. 9, figs. 10, 10 a. Hudson.

—— **reticulata** Ulrich, 1889; Contributions Micro-Palæont., pt. 2, p. 52, pl. 9, figs. 9, 9 a. Trenton.

—— **striato-marginata** (Miller) Ulrich, 1889; Contributions Micro-Palæont., pt. 2, p. 52.

For other references, see **Beyrichia striato-marginata**.

Eurypterus De Kay, 1825; Annals Lyceum Nat. Hist. N. Y., vol. 1, pt. 2, p. 375.

—— **beecheri** Hall, 1884; 2d Geol. Survey Pennsylvania, vol. PPP, p. 30, pl. 3, fig. 1. Chemung.

—— **beecheri** Hall, 1888; Pal. New York, vol. 7, p. 156, pl. 27, fig. 5.

—— **beecheri** Etheridge, Woodward, and Jones, 1888; 6th Rept. Comm. Fossil Phyllopoda Pal. Rocks, p. 9.

—— **boylei** Whiteaves, 1884; Pal. Fossils, vol. 3, pt. 1, p. 42, pl. 7, fig. 3. Guelph.

—— **dekayi** Hall, 1859; Pal. New York, vol. 3, p. 411*, pl. 82, fig. 1. Waterlime.

—— **eriensis** Whitfield, 1881; Annals New York Acad. Sci., vol. 2, p. 196. Lower Helderberg.

—— **giganteus** Pohlman, 1882; Bull. Buffalo Soc. Nat. Sci., vol. 4, p. 41, pl. 2, fig. 1. Waterlime.

—— **lacustris** Harlan, 1834; Trans. Geol. Soc. Pennsylvania, vol. 1, p. 98, pl. 5, fig. 2. Waterlime.

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Eurypterus lacustris Harlan, 1835; Med. Phys. Researches, p. 297, plate, fig. 2.
—— **lacustris** Hall, 1859; Pal. New York, vol. 3, p. 407*, pl. 81, figs. 1-11; pl. 81 a, fig. 1; pl. 81 b, figs. 1-5; pl. 83 b, fig. 3; also fig. 5 in text p. 400*.
—— **lacustris** var. **robustus** Hall, 1859; Pal. New York, vol. 3, p. 410*, pl. 81 c, fig. 2.
—— [*Dolichopterus*] **mansfieldi** Hall, C. E., 1877; Proc. Am. Philos. Soc., vol. 16, p. 621. Carboniferous.
—— **mansfieldi** Hall, 1884; 2d Geol. Survey Pennsylvania, vol. PPP, p. 32, pl. 4, figs. 1-8; pl. 5, figs. 1-11; pl. 6, fig. 1; pl. 7, fig. 1; pl. 8, figs. 1-3.
—— [*Anthraconectes*] **mazonensis** Meek and Worthen, 1868; Am. Jour. Sci., 2d series, vol. 46, p. 21. Coal Measures.
—— [*Anthraconectes*] **mazonensis** Meek and Worthen, 1868; Geol. Survey Illinois, vol. 3, p. 544, figures.
—— [*Anthraconectes*] **mazonensis** Hall, 1884; 2d Geol. Survey Pennsylvania, vol. PPP, p. 25, fig. 2; p. 27, fig. 3.
—— [*Anthraconectes*] **mazonensis** White, 1884; 13th Ann. Rept. Dept. Geol. Nat. Hist. Indiana, p. 168, pl. 37, figs. 1, 2, 3.
—— **microphthalmus** Hall, 1859; Pal. New York, vol. 3, p. 407*, pl. 80 a, fig. 7. Lower Helderberg.
—— **pachycheirus** Hall, 1859; Pal. New York, vol. 3, p. 412*, pl. 8, figs. 1-3. Waterlime.
—— **pennsylvanicus** Hall, C. E., 1877; Trans. Am. Philos. Soc. Phila., vol. 7, p. 621. Carboniferous.
—— **pennsylvanicus** Hall, 1884; 2d Geol. Survey Pennsylvania, vol. PPP, p. 31, pl. 5, fig. 18.
—— **pohlmani** Vogdes, 1889; to take the place of the preoccupied name of *E. scorpionis* Grote and Pitt. Ann. N. Y. Acad. Sci., vol. 5, No. 1.
—— **potens** Hall, 1884; 2d Geol. Survey Pennsylvania, vol. PPP, pl. 4, figs. 9, 10. Carboniferous.
—— **prominens** Hall, 1884; Proc. Am. Assoc. Adv. Sci., vol. 33, p. 420. Clinton.
—— **prominens** Hall, 1888; Pal. New York, vol. 7, p. 157, pl. 27, figs. 3, 4.
—— **pulicaris** Salter, 1863; Quart. Jour. Geol. Soc. London, vol. 19, p. 78, figs. 9, 10. Coal Measures.
—— **pulicaris** Dawson, 1868; Acadian Geology, p. 523, figs. 179 a, b.
—— **pustulosus** Hall, 1859; Pal. New York, vol. 3, p. 413*, pl. 83 b, fig. 1. Waterlime.
—— **remipes** De Kay. Waterlime.
Syn., *Fossil Fish* Mitchell, 1818; Am. Monthly Mag., vol. 3, p. 291.
—— **remipes** De Kay, 1825; Annals Lyceum Nat. Hist., vol. 1, p. 375, pl. 29.
—— **remipes** Harlan, 1834; Trans. Geol. Soc. Penn., vol. 1, p. 96, pl. 5.
—— **remipes** Harlan, 1835; Medical Phys. Researches, p. 297, pl., fig. 1.
—— **remipes** Milne-Edwards, 1840; Hist. Nat. Crust., vol. 3, p. 422.
—— **remipes** Burmeister, 1843; Org. Trilobiten, p. 62 (Ray Soc. ed., p. 54).
—— **remipes** Bronn, 1837; Lethea Geognostica, vol. 1, p. 666, pl. 9², fig. 1; pl. 9, fig. 1.
—— **remipes** Salter, 1859; Quart. Jour. Geol. Soc. London, vol. 15, p. 255.
—— **remipes** Nieszkowski, 1858; Der *Eurypterus remipes*, etc., pls. 1, 2, 3.
—— **remipes** Hall, 1859; Pal. New York, vol. 3, p. 404, pl. 80, figs. 1-12; pl. 80 a, figs. 1-6; pl. 83 b, fig. 2, also p. 403*, figs. 6, 7.
—— **remipes** (numerous authors).
—— [*Eusarcus*] **grandis** Grote and Pitt, 1875; Bull. Buffalo Soc. Nat. Sci., vol. 3, p. 17. Waterlime.

Referred by J. Pohlman (Bull. Buffalo Soc. Nat. Sci., vol. 5, p. 31) to *Eurypterus scorpionis*. An almost similar term, *E. scorpioides* was used for a species of this genus by H. Woodward in 1868; I suggest that of *E. pohlmani* for this species.

—— [*Eusarcus*] *scorpionis* Grote and Pitt, 1875; Bull. Buffalo Soc. Nat. Sci., vol. 3, pp. 1, 17, photographic plate. Waterlime.

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Eurypterus [*Eusarcus*] **scorpionis** (Grote and Pitt) Pohlman, 1886; Bull. Buffalo Soc. Nat. Sci., vol. 5, p. 30, pl. 2, fig. 3.

—— [*Eusarcus*] *grandis* (Grote and Pitt) Pohlman, 1886; Bull. Buffalo Soc. Nat. Sci., vol. 5, p. 31.

Referred to *Eurypterus pohlmani* Vogdes, 1889; Annals N. Y. Acad. Sci., vol. 5, p. 22.

Hymenocaris Salter, 1853; 22d Rept. Brit. Assoc. Adv. Sci., Trans. of sec., p. 56.

Isochilina Jones, 1857; Mem. Geol. Survey Canada, decade 3, p. 97.

—— [*Leperditia* (*Isochilina*)] **armata** Walcott, 1883; Des. New Sp. Foss. Trenton Group, p. 7.

—— [*Leperditia* (*Isochilina*)] **armata** Walcott, 1884; 35th Rept. N. Y. State Mus. Nat. Hist., p. 213.

—— **cristata** (Whitfield) Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 23, pl. 1, fig. 8. Calciferous.

For other references, see **Primitia cristata**.

—— [*Cytherina*] **cylindrica** Hall, 1852; Pal. New York, vol. 2, p. 14, pl. 4, figs. 8 a, b. Medina.

Prof. T. Rupert Jones (Quart. Jour. Geol. Soc., vol. 46, 1890, p. 8) refers this species to *Leperditia cylindrica*.

—— [*Leperditia* (*Isochilina*)] **cylindrica** Jones, 1858; Annals Mag. Nat. Hist., 3d series, vol. 1, p. 253; also, Geol. Survey Canada, decade 3, p. 101.

—— [*Leperditia* (*Isochilina*)] **cylindrica** Hall, 1871; Description n. sp. Fossils Hudson River Group.

—— [*Leperditia* (*Isochilina*)] **cylindrica** Hall, 1872; 24th Rept. N. Y. State Mus. Nat. Hist., p. 231, pl. 8, fig. 2; also, Pal. Ohio, vol. 2, 1875, p. 101, pl. 4, fig. 5.

Prof. T. Rupert Jones (Quart. Jour. Geol. Soc., vol. 46, 1890, p. 8) refers this species to *Primitia minuta* Eichwald.

—— **cylindrica** Miller, 1875; Cincinnati Quart. Jour. Sci., vol. 2, p. 351.

—— **fabacea** Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 22, pl. 2, fig. 11. Hamilton.

—— [*Leperditia* (*Isochilina*)] **gracilis** Jones, 1858; Annals Mag. Nat. Hist., London, 3d series, vol. 1, p. 248, pl. 10, fig. 2; also, Geol. Survey Canada, decade 3, p. 98, pl. 2, fig. 15. Trenton.

—— **gregaria** (Whitfield) Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 22, pl. 1, figs. 9, 10.

For other references, see **Primitia gregaria**.

—— **jonesi** Wetherby, 1881; Jour. Cincinnati Soc. Nat. Hist., vol. 4, p. 80, pl. 2, figs. 7, 7 a. Subcarboniferous.

—— **lineata** Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 21, pl. 2, figs. 5 a, b, 8 a, b. Hamilton.

—— [*Leperditia* (*Isochilina*)] **minutissima** Hall, 1871; Des. New Species Foss. Hudson River Group, p. 7.

—— [*Leperditia* (*Isochilina*)] **minutissima** Hall, 1872; 24th Rept. New York State Mus. Nat. Hist., p. 231, pl. 8, fig. 13.

—— [*Leperditia* (*Isochilina*)] **minutissima** Hall and Whitfield, 1875; Pal. Ohio, vol. 2, p. 102, pl. 4, fig. 5. (See **Aparchites minutissima**.)

—— [*Leperditia* (*Isochilina*)] **ottawa** Jones, 1858; Annals Mag. Nat. Hist., London, 3d series, vol. 1, p. 248, pl. 11, fig. 1. Chazy.

—— [*Leperditia* (*Isochilina*)] **ottawa** Jones, 1858; Geol. Survey Canada, decade 3, p. 97, pl. 9, fig. 14.

—— **ottawa** Jones, 1884; Annals Mag. Nat. Hist., London, 5th series, vol. 14, p. 345.

—— **seelyi** (Whitfield) Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 22, pl. 1, fig. 7.

For other references, see **Primitia seelyi**.

Klœdenia Jones and Holl, 1886; Annals Mag. Nat. Hist., London, 5th series, vol. 17, p. 362.

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Klœdenia [*Beyrichia*] **notata** Hall, 1859; Pal. New York, vol. 3, p. 379, pl. 79 b, figs. 3 a, b, c. Lower Helderberg.

—— [*Beyrichia*] **notata** var. **ventricosa** Hall, 1859; *idem*, p. 380, pl. 79 b, figs. 4 a, b, c.

—— **notata** Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 13, pl. 4, figs. 22, 23.

—— **notata** var. **ventricosa** Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 14, pl. 1, figs. 1 a, b; pl. 4, fig. 24.

—— **pennsylvanica** Jones, 1889; American Geologist, vol. 4, p. 341, pl., figs. 5–9. Lower Helderberg.

—— **simplex** Jones, 1889; American Geologist, vol. 4, p. 338, pl., fig. 14. Upper Devonian.

Leaia Jones, 1862; Mon. Fossil Estheriæ, p. 115.

—— [*Cypricardia*] **leidyi** Lea, 1855; Proc. Acad. Nat. Sci. Phila., vol. 7, p. 341, pl. 4. Coal Measures.

—— **leidyi** Jones, 1862; Mon. Fossil Estheriæ, p. 116, pl. 5, figs. 11, 12.

—— **leidyi** Dawson, 1868; Acadian Geology, p. 256, fig. 78 c.

—— **leidyi** Packard, 1882; 12th Rept. U. S. Geol. Survey Territories, p. 358, fig. 24.

—— **leidyi** Jones, 1870; Geol. Mag., vol. 7, p. 219, pl. 9, fig. 11; also, Geol. Mag., decade 3, vol. 1, p. 361, pl. 12, fig. 13.

—— **tricarinata** Meek and Worthen, 1868; Geol. Survey Illinois, vol. 3, p. 541, figs. B_1, B_2, B_3. Coal Measures.

—— **tricarinata** White, 1884; 13th Ann. Rept. Dept. Geol. Nat. Hist. Indiana, p. 167, pl. 39, figs. 10–13.

Leperditia Rouault, 1851; Bull. Soc. Géol. France, 2d series, vol. 8, p. 377.

—— [*Cytherina*] **alta** Conrad, 1842; Geol. Rept. New York, 3d Geol. Dist. (Vanuxem), p. 112. Lower Helderberg.

—— [*Cytherina*] **alta** ? Hall, 1852; Pal. New York, vol. 2, p. 338, pl. 78, figs. 2 a–d. Referred to *Leperditia jonesi* Hall, *idem*, vol. 3, p. 372.

—— **alta** Jones, 1856; Annals and Mag. Nat. Hist., London, 2d series, vol. 17, p. 88, pl. 7, figs. 6, 7.

—— **alta** Jones, 1858; Annals Mag. Nat. Hist., London, 3d series, vol. 1, p. 250, pl. 10, figs. 10, 11.

—— **alta** Hall, 1859; Pal. New York, vol. 3, p. 373, pl. 79 a, figs. 6 a–e.

—— **alta** Meek, 1873; Pal. Ohio, vol. 1, p. 187, pl. 17, figs. 2 a, b.

—— **alta** Jones, 1881; Annals Mag. Nat. Hist., London, 5th series, vol. 8, p. 346.

—— **alta** Whitfield, 1882; Geol. Wisconsin, vol. 4, p. 323, pl. 25, figs. 8, 9.

—— **alta** Jones, 1884; Annals Mag. Nat. Hist., London, 5th series, vol. 14, p. 343.

—— **alta** Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 25, pl. 1, figs. 6 a, b.

—— **amygdalina** Jones, 1858; Annals Mag. Nat. Hist., London, 3d series, vol. 1, p. 341. Trenton.

—— **amygdalina** Jones, 1858; Geol. Survey Canada, decade 3, p. 97, pl. 11, figs. 18, 19.

—— **amygdalina** Jones, 1881; Annals Mag. Nat. Hist., London, 5th series, vol. 8, p. 344, pl. 19, fig. 9.

—— **amygdalina** Jones, 1884; Annals Mag. Nat. Hist., London, 5th series, vol. 14, p. 342.

—— **angulifera** Whitfield, 1881; Annals New York Acad. Sci., vol. 2, p. 199. Lower Helderberg.

—— **anna** Jones, 1858; Annals Mag. Nat. Hist., London, 3d series, vol. 1, p. 347, pl. 9, fig. 8. Calciferous.

—— **anna** Jones, 1858; Geol. Survey Canada, decade 3, p. 96, pl. 11, fig. 13.

—— **anticostiana** Jones, 1884; Annals Mag. Nat. Hist., London, 3d series, vol. 14, p. 241. Hudson.

Syn., *canadensis* var. *anticostiana* Jones, 1858; Annals Mag. Nat. Hist., London, 3d series, vol. 1, p. 341. Hudson.

canadensis var. *anticostiana* Jones, 1858; Geol. Survey Canada, decade 3, p. 95, pl. 11, fig. 17.

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Leperditia antioostiana Billings, 1866; Catalogue Sil. Foss., Anticosti, p. 68.
Syn., *fabulites* (Conrad) var. *anticostiana* Jones, 1881; Annals Mag. Nat. Hist., London, 5th series, vol. 8, p. 344, pl. 19, fig. 8.

—— **arctica** Jones, 1856; Annals Mag. Nat. Hist., London, 2d series, vol. 17, p. 87, figs. 1–5. Upper Silurian.
Syn., *balthica* var. *arctica* (Jones) Salter, 1852; Appendix Sutherland's Jour. Voyage Baffin's Bay, vol. 2, p. ccxxi, pl. 5, fig. 13.
balthica var. *arctica* (Jones) Salter, 1853; Quart. Jour. Geol. Soc. London, vol. 9, p. 314.

—— **argenta** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 146, pl. 8, fig. 5. Middle Cambrian.

—— **billingsi** Jones, 1856; Annals Mag. Nat. Hist., London, 2d series, vol. 8, p. 345, pl. 15, fig. 9. Trenton.

—— **bivertex** Ulrich, 1879; Jour. Cincinnati Soc. Nat. Hist., vol. 2, p. 11, pl. 7, figs. 5, 5 a. Hudson.

—— **bivia** White, 1874; Rept. Invert. Foss. U. S. Geog. and Geol. Survey W. 100th Mer., p. 11. Quebec.

—— **bivia** White, 1877; U. S. Geog. and Geol. Survey W. 100th Mer., Palæont., vol. 4, p. 58, pl. 3, figs. 7 a–d.

—— *byrnesi* Miller, 1874; Cincinnati Quart. Jour. Sci., vol. 1, p. 123, fig. 10. (See **Æchmina beyrnesi.**) Hudson.

—— **cæcigena** Miller, 1881; Jour. Cincinnati Soc. Nat. Hist., vol. 1, p. 263, pl. 6, figs. 5, 5 a. Hudson.

—— **canadensis** Jones, 1858; Annals Mag. Nat. Hist., London, 3d series, vol. 1, p. 244, pl. 9, figs. 11–15. Chazy and Trenton.

—— **canadensis** Jones, 1858; Geol. Survey Canada, decade 3, p. 92; var. *nana*, pl. 11, figs. 6, 7, 9, 10, and *labrosa*, pl. 11, fig. 8.

—— **canadensis** Jones, 1881; Annals Mag. Nat. Hist., London, 5th series, vol. 14, p. 340.
Compare *Leperditia turgida*, *L. concinnula*, and *L. ventralis*.

—— *canadensis* var. *pauquettiana* Jones. (See **Leperditia louckana.**)

—— [*Cythere*] **carbonaria** Hall, 1858; Trans. Albany Inst., vol. 4, p. 33. Warsaw.

—— **carbonaria** Whitfield, 1882; Bull. Am. Mus. Nat. Hist., New York, vol. 1, p. 94, pl. 9, figs. 24–27.

—— *capax* Safford; Geol. Tennessee. (Not defined.)

—— **cayuga** Hall, 1861; Des. New Species Foss., p. 83. Corniferous.

—— **cayuga** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 111.

—— **claypolei** Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 25, pl. 3, figs. 17 a–c. Cincinnati.

—— **concinnula** Billings, 1865; Pal. Fossils, vol. 1, p. 299. Quebec.

—— **crepiformis** Ulrich, 1879; Jour. Cincinnati Soc. Nat. Hist., vol. 2, p. 10, pl. 7, figs. 3, 3 a. Hudson.

—— [*Cytherina*] **cylindrica** Hall, 1852; Pal. N. Y., vol. 2, p. 14, pl. 4, figs. 8 a, b.
For other references, see **Isochilina cylindrica.** Medina.

—— **dermatoides** Walcott, 1887; Am. Jour. Sci., 3d series, vol. 34, p. 192, pl. 1, figs. 13, 13 a. Cambrian.

—— **faba** Hall, 1876; 28th Rept. New York State Mus. Nat. Hist., Expl., pl. 32, figs. 1–3. Niagara.

—— **faba** Hall, 1879; 28th Rept. New York State Mus. Nat. Hist., p. 186, pl. 32, figs. 1–3 (2d ed.).

—— **faba** Hall, 1882; 11th Ann. Rept. Dept. Geol. Nat. Hist. Indiana, p. 331, pl. 34, figs. 1–3.

—— [*Cytherina*] **fabulites** Conrad, 1843; Proc. Acad. Nat. Sci. Phila., vol. 1, p. 332. Trenton.

—— **fabulites** Jones, 1856; Annals Mag. Nat. Hist., London, 2d series, vol. 17, p. 89.

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Leperditia fabulites Jones, 1858; Annals Mag. Nat. Hist., London, 3d series, vol. 1, p. 341.

—— **fabulites** Jones, 1881; Annals Mag. Nat. Hist., London, 4th series, vol. 8, p. 342.

—— **fabulites** Whitfield, 1883; Geol. Wisconsin, vol. 1, p. 60, fig. 5.

—— **fabulites** Jones, 1884; Annals Mag. Nat. Hist., London, 5th series, vol. 14, p. 342.

—— **fonticola**, 1867; 20th Rept. New York State Cab. Nat. Hist., p. 335, pl. 21, figs. 1–3. Niagara.

—— **fonticola**, 1870; 20th Rept. New York State Cab. Nat. Hist. (rev. ed.), p. 428, pl. 21, figs. 1–3.

—— **gibbera** Jones, 1856; Annals Mag. Nat. Hist., London, 2d series, vol. 17, p. 90, pl. 7, figs. 1–3. Niagara.

—— **gibbera** Jones, 1858; Annals Mag. Nat. Hist., London, 3d series, vol. 1, p. 250, pl. 10, figs. 7–9.

—— **gibbera** var. **scalaris** Jones, 1858; Geol. Survey Penn., vol. 2, p. 834, fig. 698.

—— *gracilis*. (See **Isochilina gracilis**.)

—— **hudsonica** Hall, 1859; Pal. New York, vol. 3, p. 375, pl. 79 a, figs. 7 a, b, c. Lower Helderberg.

—— **hudsonica** Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 24, pl. 1, figs. 5 a–c, 11 a–c; pl. 3, fig. 20 (?)

—— **jonesi** Hall, 1859; Pal. New York, vol. 3, p. 272, pl. 79 a, figs. 5 a–e. Lower Helderberg.

—— **jonesi** Jones, 1884; Annals Mag. Nat. Hist., London, 5th series, vol. 1, p. 343.

Syn., *alta* Hall, 1852; Pal. New York, vol. 2, p. 338, pl. 78, figs. 2 a–d.

—— **josephiana** Jones, 1884; Annals Mag. Nat. Hist., London, 5th series, vol. 1, p. 341. Trenton.

Syn., *canadensis* var. *josephiana* Jones, 1858; Annals Mag. Nat. Hist., London, 3d series, vol. 1, p. 341.

canadensis var. *josephiana* Jones, 1858; Geol. Survey Canada, decade 3, p. 94, pl. 11, fig. 16.

fabulites var. *josephiana* Jones, 1881; Annals Mag. Nat. Hist., London, 5th series, vol. 8, p. 344, pl. 19, fig. 7; pl. 20, figs. 7, 8; also, p. 345, pl. 20, fig. 4 (?).

—— *labrosa*. (See **Leperditia canadensis**.)

—— **louckiana** Jones, 1884; Annals Mag. Nat. Hist., London, 5th series, vol. 1, p. 341. Trenton.

Syn., *canadensis?* Jones, 1858; Annals Mag. Nat. Hist., London, 3d series, vol. 1, p. 245, pl. 9, figs. 16, 17.

Afterwards var. *louckiana* and *Leperditia canadensis* var. *pauquettiana*.

canadensis var. *louckiana* Jones, 1858; Geol. Survey Canada, decade 3, p. 93, pl. 11, fig. 11.

fabulites var. *louckiana* Jones, 1881; Annals Mag. Nat. Hist., London, 5th series, vol. 8, p. 343.

—— [*Cypridina*] **marginata** Keyserling, 1846; Wiss. Beob. auf einer Reise in das Petochora-Land, p. 288, pl. 11, fig. 16.

—— **marginata** Jones, 1858; Annals Mag. Nat. Hist., London, 3d series, vol. 17, p. 91, pl. 7, figs. 11, 14, 15.

Syn., *Cyridina balthica* Eichwald (not *Cytherina balthica* Hisinger) Bull. Soc. Nat. Moscou, 1854, No. 1, p. 99, pl. 2, fig. 6.

—— [*Isochilina*] *minutissima* Hall. (See **Isochilina minutissima**.)

—— *morgani* Safford; Geol. Tennessee. (Not defined.)

—— **Nana?** Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 27, pl. 4, fig. 4. (See, also, **Leperditia canadensis** var. **nana**.)

—— **okeni** (Münster) Dawson, 1868; Acadian Geology, p. 256, fig. 78 b. Lower Carboniferous.

—— *ottawa*. (See **Isochilina ottawa**.)

—— **ovata** Jones, 1858; Annals Mag. Nat. Hist., London, 3d series, vol. 1, p. 252, pl. 10, fig. 14. Trenton

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Leperditia ovata Jones, 1858; Geol. Survey Penn., vol. 2, p. 834, fig. 697.
—— *pauquettiana*. (See **Leperditia canadensis** var. **pauquettiana**.)
—— *parasitica* Hall, 1859; Pal. New York, vol. 3, p. 376, pl. 79 a, figs. 8 a, b. Lower Helderberg.
Referred by T. R. Jones to **Beyrichia parasitica**, which see.
—— **parvula** Hall, 1859; Pal. New York, vol. 3, p. 376, pl. 79 a, figs. 9 a, b. Lower Helderberg.
—— **pennsylvanica** Jones, 1858; Annals Mag. Nat. Hist., London, 3d series, vol. 1, p. 251, pl. 10, figs. 12, 13. Clinton.
—— **pennsylvanica** Jones, 1858; Geol. Survey Penn., vol. 2, p. 834, fig. 699.
—— *punctulifera* Hall, 1860; 13th Rept. New York State Cab. Nat. Hist., p. 92. (See **Primitiopsis punctulifera**.) Hamilton.
—— **radiata** Ulrich, 1879; Jour. Cincinnati Soc. Nat. Hist., vol. 2, p. 9, pl. 7, figs. 2 a, b. Utica.
—— **rotundata** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 206, pl. 16, fig. 5. Devonian.
—— **scalaris** (**Leperditia gibbera** var. **scalaris** Jones, 1858); Annals Mag. Nat. Hist. London, 3d series, vol. 1, p. 250, pl. 10, figs. 7–9. Waterlime.
—— **seneca** Hall, 1861; Des. New Species Fossils, p. 84. Hamilton.
—— **seneca** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 112.
—— **seneca** Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 23, pl. 1, figs. 13, 14.
—— **sinuata** Hall, 1860; Canadian Naturalist, vol. 5, p. 158. Upper Silurian.
—— **sinuata** Dawson, 1868; Acadian Geology, p. 609, fig. 217.
—— **sinuata** Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 24, pl. 1, figs. 12 a–c.
—— **spinulifera** Hall, 1861; Des. New Species Fossils, p. 83. Corniferous.
—— **spinulifera** Hall, 1862; 15th Rept. New York State Cab. Nat. Hist., p. 111.
—— [*Cythere*] **sublaevis** Shumard, 1855; 1st and 2d Ann. Rept. Geol. Survey Missouri, p. 195, pl. B, fig. 15. Lower Magnesian.
—— **subquadrata** Jones, 1889; American Geologist, vol. 4, p. 340, pl., figs. 4 a–d. Lower Helderberg.
—— *troyensis* Ford. (See **Aristozoe troyensis**.)
—— **unicornis** Ulrich, 1879; Jour. Cincinnati Soc. Nat. Hist., vol. 2, p. 10, pl. 7, figs. 4, 4 a, b. Hudson.
Referred by Prof. T. R. Jones to *Primitia unicornis*.
—— **ventralis** Billings, 1865; Pal. Fossils, vol. 1, p. 300. Quebec.
Lepidocoleus Faber, 1886; Jour. Cincinnati Soc. Nat. Hist., vol. 9, p. 15.
—— **jamesi** (Hall and Whitfield) Faber, 1886; *idem*, vol. 9, p. 15, pl. 1, figs. a–f. Hudson.
For other references, see **Pumulites jamesi**.
Lisgocaris Clarke, 1882; Am. Jour. Sci., 3d series, vol. 23, p. 478.
—— **lutheri** Clarke, 1882; Am. Jour. Sci., 3d series, vol. 23, p. 478, pl. 1, fig. 5. Hamilton.
Mesothyra Hall, 1888; Pal. New York, vol. 7, p. 187.
—— [*Dithyrocaris*] **neptuni** Hall, 1876; Illus. Devonian Fos., pl. 23 (not pl. 22, figs. 1–5); pl. 23, figs. 1–3. Hamilton.
—— [*Dithyrocaris*] **neptuni** Packard, 1878; 12th Rept. U. S. Geol. Survey Territories, p. 452, fig. 73.
—— [*Dithyrocaris*] **neptuni** Etheridge, Woodward, and Jones, 1887; 5th Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 8.
—— **neptuni** Hall, 1888; Pal. New York, vol. 7, p. 191, pl. 32, fig. 7; pl. 33, fig. 1.
—— **neptuni** Etheridge, Woodward, and Jones, 1888; 6th Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 8.
Syn., *oceani* Hall, 1888; Pal. New York, vol. 7, p. 187, pl. 32, figs. 1–6; pl. 33, fig. 4–7; pl. 34, figs. 1–5. Portage.
—— [*Dithyrocaris*] **neptuni** Hall, 1876; Illus. Devonian Foss., pl. 22, figs. 1–5; pl. 33, figs. 1–3.

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Mesothyra [*Dithyrocaris*] **neptuni** Etheridge, Woodward, and Jones, 1887; 5th Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 8.
Syn., *Mesothyra oceani* Etheridge, Woodward, and Jones, 1888; 6th Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 8.
—— **stumea** Hall, 1888; Pal. New York, vol. 7, p. 193, pl. 32, figs. 8, 9; pl. 34, fig. 2. Hamilton.
—— **stumea** Etheridge, Woodward and Jones, 1888; 6th Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 8.
—— [*Dithyrocaris?*] **veneris** Hall, 1888; Pal. New York, vol. 7, p. 193, pl. 33, fig. 3. Hamilton.
—— [*Dithyrocaris?*] **veneris** Etheridge, Woodward, and Jones, 1888; 6th Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 8.
Neolimulus Woodward, 1868; Geol. Mag., vol. 5, p. 1.
Type, *Neolimulus falcatus* Woodward.
Nothozoe Barrande, 1872; Syst. Sil. Bohême, vol. 1, suppl., p. 536.
Type, *Nothozoe pollens* Barrande.
—— **vermontana** Whitfield, 1884; Bull. Am. Mus. Nat. Hist., vol. 1, p. 144, pl. 14, figs. 14, 15. Potsdam.
Palæocaris Meek and Worthen, 1865; Proc. Acad. Nat. Sci. Phila., vol. 17, p. 48.
—— **typus** Meek and Worthen, 1865; Proc. Acad. Nat. Sci. Phila., vol. 17, p. 49.
Syn., *Acanthotelson inæqualis* Meek and Worthen, 1865; Proc. Acad. Nat. Sci. Phila., vol. 17, p. 48. Coal Measures.
Acanthotelson inæqualis Meek and Worthen, 1866; Geol. Illinois, vol. 2, p. 403, pl. 32, fig. 7, 7 a.
—— **typus**, Meek and Worthen, 1866; Geol. Illinois, vol. 2, p. 405, pl. 32, figs. 5 a–d.
—— **typus** Meek and Worthen, 1868; Geol. Illinois, vol. 3, p. 552, figs. a, b.
—— **typus** Peach, 1880; Trans. Royal Soc. Edinburgh, vol. 30, p. 85, pl. 10, figs. 10 g, 10 h.
—— **typus** Brocchi, 1880; Bull. Soc. Géol. France, vol. 8, p. 9, pl. 1, figs. 8–10.
—— **typus** Woodward, 1881; Geol. Mag., decade 2, vol. 8, p. 533, wood-cut.
—— **typus** White, 1884; 13th Ann. Rept. Dept. Geol. Nat. Hist. Indiana, p. 179, pl. 38, figs. 1. 2, 3.
—— **typus** Packard, 1885; Am. Naturalist, vol. 19, p. 790.
—— **typus** Packard, 1886; Mem. Nat. Acad. Sci., vol. 3, p. 129, pl. 3, figs. 1–4; pl. 7, figs. 1, 2.
Palæocrangon Salter, 1861. (See **Crangopsis** Salter, 1863.)
Palæopalæmon Whitfield, 1880; Am. Jour. Sci., 3d series, vol. 19, p. 40.
—— **newberryi** Whitfield, 1880; Am. Jour. Sci., 2d series, vol. 19, p. 41. Erie.
—— **newberryi** Whitfield, 1880; Author's Edition, plate, figs. 1, 2, 3.
—— **newberryi** Hall, 1888; Pal. New York, vol. 7, p. 203, pl. 30, figs. 20–23.
Palæocreusia Clarke, 1888; Pal. New York, vol. 7, p. 210.
—— **devonica** Clarke, 1888; Pal. New York, vol. 7, p. 210, pl. 36, figs. 24, 26. Corniferous.
Plumulites Barrande, 1872; Syst. Sil. Bohême, suppl., vol. 1, p. 565.
—— **devonicus** Clarke, 1882; Am. Journ. Sci., 3d series, vol. 24, p. 55, figs. 1, 2. Hamilton.
—— **jamesi** Hall and Whitfield, 1875; Pal. Ohio, vol. 2, p. 106, pl. 4, figs. 1–3. Hudson.
—— ? **jamesi** Miller, 1875; Cincinnati Quart. Jour. Sci., vol. 2, p. 275, fig. 19.
Referred by Faber (Jour. Cincinnati Soc. Nat. Hist., vol. 9, 1886, p. 15) to a new genus under the name of *Lepidocoleus*.
—— **newberryi** Whitfield, 1881; Annals New York Acad. Sci., vol. 2, p. 217. Huron.
Prestwichia Woodward, 1867; Quart. Jour. Geol. Soc. London, vol. 23, p. 32.

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Prestwichia danæ (Meek and Worthen) Packard, 1886; Mem. Nat. Acad. Sci., vol. 3, p. 146, pl. 5, figs. 3, 39; pl. 6, figs. 1 a, 2, 2 a.

For other references to this species, see **Euproops** and **Belinurus**.

—— *eriensis* Williams. (See **Protolimulus eriensis**.)

Protolimulus Packard, 1866; Mem. Nat. Acad. Sci., vol. 3, p. 150.

—— [*Prestwichia*] **eriensis** Williams, 1885; Am. Jour. Sci., 3d series, vol. 30, p. 45, 3 figs. Devonian.

—— [*Protolimulus*] **eriensis** Packard, 1886; Mem. Nat. Acad. Sci., vol. 3, p. 150, figs. 11–13.

—— **eriensis** Hall, 1888; Pal. New York, vol. 7, p. 153, pl. 26, figs. 1, 2.

Primitia Jones and Holl, 1865; Annals Mag. Nat. Hist., 3d series, London, vol. 16, p. 415.

Primitia *cristata* Whitfield, 1889; Bull. Am. Mus. Nat. Hist., New York, vol. 2, p. 59, pl. 13, figs. 1, 2. (See **Isochilina cristata**.)

—— *gregaria* Whitfield, 1889; Bull. Am. Mus. Nat. Hist., New York, vol. 2, p. 58, pl. 13, figs. 3–5. (See **Isochilina gregaria**.)

—— **lativia** Ulrich, 1889; Contributions Micro-Palæont., pt. 2, p. 50, pl. 9, figs. 8, 8 a. Hudson.

—— [*Beyrichia*] *logani* var. *leperditioides* Jones, 1858; Annals and Mag. Nat. Hist., London, 3d series, vol. 1, p. 244, pl. 9, fig. 10. Trenton.

—— [*Beyrichia*] *logani* var. *leperditoides* Jones, 1858; Geol. Survey Canada, decade 3, p. 91, pl. 11, figs. 1–5.

—— **leperditioides** Jones, 1884; Annals and Mag. Nat. Hist., 6th series, London, vol. 14, p. 345.

—— **mundula** Jones, 1889; American Geologist, vol. 4, p. 337, pl., figs. 1, 2, 10, 15. Upper Devonian.

—— [*Beyrichia* (*Primitia*)] **occidentalis** Walcott, 1884; Pal. Eureka Dist., Mon. U. S. Geol. Survey, vol. 8, p. 204, pl. 17, figs. 4, 4 a. Devonian.

—— [*Beyrichia?*] **parallela** Ulrich, 1889; Contributions Micro-Palæont., pt. 2, p. 51, pl. 9, figs. 7–7 a. Hudson.

—— **pennsylvanica** Jones, 1889; American Geologist, vol. 4, p. 339, pl., figs. 15 a, b. Marcellus.

—— **seminulum** Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 5, pl. 2, fig. 2. Hamilton.

—— *seelyi* Whitfield, 1889; Bull. Am. Mus. Nat. Hist., N. Y., vol. 2, p. 60, pl. 13, figs. 15–21. (See **Isochilina seelyi**.)

—— **unicornis** (Ulrich) Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 7, pl. 11, figs. 8–13.

For other references, see **Beyrichia unicornis** Ulrich. The species is referred by Ulrich (Contributions Micro-Palæont., pt. 2, p. 50) to *Aparchites unicornis*, pl. 9, fig. 11.

—— **whitfieldi** Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 9, pl. 3, figs. 24 a, b. Cincinnati.

Primitiopsis Jones, 1887; Notes on some Sil. Ostracoda from Gothland, p. 5.

—— **punctulifera** (Hall) Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 9, pl. 2, figs. 7 a, b, 12 a, b. Hamilton.

For other references, see **Beyrichia punctulifera** Hall.

Protobalanus Whitfield, 1889; Bull. Am. Mus. Nat. Hist., New York, vol. 2, p. 66; Hall, 1888; Pal. New York, vol. 7, pp. lxii and 209.

—— **hamiltonensis** (Whitfield) Hall, 1888; Pal. New York, vol. 7, p. 209, pl. 36, fig. 23.

—— **hamiltonensis** Whitfield, 1889; Bull. Am. Mus. Nat. Hist., New York, vol. 2, p. 67, pl. 13, fig. 22. Marcellus.

Protocaris Walcott, 1884; Bull. U. S. Geol. Survey, No. 10, p. 50.

—— **marshi** Walcott, 1884; Bull. U. S. Geol. Survey, No. 10, p. 50, pl. 10. Cambrian.

—— **marshi** Walcott, 1886; Bull. U. S. Geol. Survey, No. 30, p. 148, pl. 15, fig. 1.

Pterygotus Agassiz, 1844; Mon. Poissons Fossiles, note, p. xix.
—— **acuticauda** Pohlman, 1882; Bull. Buffalo Soc. Nat. Sci., vol. 4, p. 42, pl. 2, fig. 3. Waterlime.
—— **bilobus** (Huxley and Salter) Pohlman, 1886; Bull. Buffalo Soc. Nat. Sci., vol. 5, p. 27. Waterlime.
—— **buffaloensis** Pohlman, 1881; Bull. Buffalo Soc. Nat. Sci., vol. 4, p. 17, figs. 1, 2. Waterlime.
—— **buffaloensis** Pohlman, 1882; Bull. Buffalo Soc. Nat. Sci., vol. 4, p. 44, pl. 3, fig. 3.
—— **buffaloensis** Pohlman, 1886; Bull. Buffalo Soc. Nat. Sci., vol. 5, p. 24, pl. 3, fig. 1.
—— **canadensis** Dawson, 1881; Canadian Naturalist, new series, vol. 9, p. 103, figs. 1, 2. Niagara.
—— **cobbi** Hall, 1859; Pal., New York, vol. 3, p. 417, pl. 83 b, fig. 4; pl. 84, fig. 8 (?). Waterlime.
—— **cummingsi** Grote and Pitt, 1875; Bull. Buffalo Soc. Nat. Sci., vol. 3, p. 18, figure. Waterlime.
—— **cummingsi** Grote and Pitt, 1878; Proc. Am. Assoc. Adv. Sci., 26th Meeting, p. 300, figure.
—— **globicaudatus** Pohlman, 1882; Bull. Buffalo Soc. Nat. Sci., vol. 4, p. 42, pl. 2, fig. 2. Waterlime.
—— **macrophthalmus** Hall, 1859; Pal. New York, vol. 3, p. 418, pl. 80 a, figs. 8, 8 a. Waterlime.
—— **macrophthalmus** Pohlman, 1882; Bull. Buffalo Soc. Nat. Sci., vol. 4, p. 44.
—— **osborni** Hall, 1859; Pal. New York, vol. 3, p. 419, pl. 80 a, fig. 9. Waterlime.
—— **quadricaudatus** Pohlman, 1882; Bull. Buffalo Soc. Nat. Sci., vol. 4, p. 43, pl. 3, fig. 1. Waterlime.
Rachura Scudder, 1878; Proc. Boston Soc. Nat. Hist., vol. 19, p. 296.
Probably the same as the genus *Dithyocaris*.
—— *venosa* Scudder, 1878; Proc. Boston Soc. Nat. Hist., vol. 19, p. 296. Coal Measures.
—— [*Dithyocaris?*] *venosa* Etheridge, Woodward, and Jones, 1888; 6th Rept. Comm. Foss. Phyllopoda, p. 4.
Rhinocaris Clarke, 1888; Pal. New York, vol. 7, p. lviii.
—— **columbina** Clarke, 1888; Pal. New York, vol. 7, p. 195, pl. 31, figs. 16–21. Hamilton.
—— **columbina** Etheridge, Woodward, and Jones, 1888; 6th Rept. Comm. Foss. Phyllopoda, etc., p. 8.
—— **scaphoptera** Hall, 1888; Pal. New York, vol. 7, p. 197, pl. 31, figs. 22, 23. Hamilton.
—— **scaphoptera** Etheridge, Woodward, and Jones, 1888; 6th Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 8.
Schizodiscus Clarke, 1888; Pal. New York, vol. 7, p. 207.
—— **capra** Clarke, 1888; Pal. New York, vol. 7, p. 207, pl. 25, figs. 1–9. Hamilton.
Spathiocaris Clarke, 1882; Am. Jour. Sci., 3d series, vol 23, p. 477.
—— **emersoni** Clarke, 1882; Am. Jour. Sci., 3d series, vol. 23, p. 477, pl., figs. 1–3. Hamilton.
—— **emersoni** Packard, 1883; 12th Rept. U. S. Geol. Survey Territories, p. 451.
—— **emersoni** Clarke, 1886; Neues Jarbuch für Mineral., p. 180.
—— **emersoni** Woodward and Jones, 1884; 2d Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 7.
—— **emersoni** Clarke, 1885; Bull. U. S. Geol. Survey, No. 16, p. 46.
—— **emersoni** Etheridge, Woodward, and Jones, 1885; 3d Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 3.
—— **emersoni** Hall, 1888; Pal. New York, vol. 7, p. 199, pl. 35, figs. 12–18.
—— **emersoni** Etheridge, Woodward, and Jones, 1888; 6th Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 8.

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Solenocaris Meek, 1871; Proc. Acad. Nat. Sci. Phila., vol. 23, p. 335.
The name *Solenocaris* was used for a species of fossil crustacea by Mr. J. Young in 1868. Change to *Strigocaris*.

—— *ludovici* Worthen, 1884; Bull. Illinois State Cab. Nat. Hist., No. 2, p. 3. St. Louis.

—— [*Ceratiocaris* (*Solenocaris*)] *strigata* Meek, 1872; Proc. Acad. Nat. Sci. Phila., vol. 23, p. 335. Waverly.

—— [*Ceratiocaris* (*Solenocaris*)] *strigata* Meek, 1875; Pal. Ohio, vol. 2, p. 321, pl. 18, figs. 4 a–c.

Strigocaris, name suggested to replace preoccupied generic name *Solenocaris* (Meek) Vogdes, 1889; Annals N. Y. Acad. Sci., vol. 5, p. 34.

—— [*Solenocaris*] **st. ludovici** Worthen, 1884; Bull. Illinois State Cab. Nat. Hist., No. 2, p. 3. St. Louis.

—— [*Ceratiocaris* (*Solenocaris*)] **strigata** Meek, 1872; Proc. Nat. Acad. Sci. Phila., vol. 23, p. 335. Waverly.

—— [*Ceratiocaris* (*Solenocaris*)] **strigata** Meek, 1875; Pal. Ohio, vol. 2, p. 321, pl. 18, figs. 4 a–c.

Strobilepsis Clarke, 1888; Pal. New York, vol. 7, p. 212.

—— **spinigera** Clarke, 1888; Pal. New York, vol. 7, p. 212, pl. 36, figs. 20–22. Hamilton.

Stylonurus Page, 1856; Advance Text-book Geology.

—— **excelsior** Hall, MSS. Catskill.

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—— **excelsior** Hall, 1884; 36th Rept. New York State Mus., p. 77, pl. 5, fig. 1.

—— **excelsior** Hall, 1885; Proc. Am. Assoc. Adv. Sci., 33d Meeting, p. 421.

—— **excelsior** Hall, 1888; Pal. New York, vol. 7, p. 156, pl. 26; also p. 221, pl. 26 a.
Compare *Dolichocephala lacoana* Claypole.

—— [*Equistides*] **wrightianus** Dawson, 1881; Quart. Jour. Geol. Soc., vol. 37, p. 303, pl. 12, fig. 10; pl. 13, fig. 20. Portage.

—— [*Equistides*] **wrightianus** (Dawson) Wright; 35th Rept. New York State Mus. Nat. Hist., Expl., pl. 15, note, figs. 1, 2.

—— [*Echinocaris*] **wrightianus** Jones and Woodward, 1884; Geol. Mag., decade 3, vol. 1, p. 3, pl. 13, figs. 1 a, b.

—— [*Echinocaris*] **wrightianus** Etheridge, Woodward, and Jones, 1885; 3d Rept. Comm. Fossil Phyllopoda Pal. Rocks, p. 35.

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—— **quadrilirata** (Hall and Whitfield) Ulrich, 1889; Contributions Micro-Palæont., pt. 2, p. 54, pl. 9, fig. 12.
For other references, see **Beyrichia quadrilirata**.

—— **sigmoidalis** Jones, 1890; Quart. Jour. Geol. Soc., vol. 46, p. 11, pl. 2, fig. 4. Hamilton.

Tropidocaris Beecher, 1884; 2d Geol. Survey Pennsylvania, vol. PPP, p. 15.

—— **alternata** Beecher, 1884; 2d Geol. Survey Penn., vol. PPP, p. 19, pl. 2, figs. 7, 8. Chemung.

—— **alternata** Etheridge, Woodward, and Jones, 1885; 3d Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 35.

—— **alternata** Hall, 1888; Pal. New York, vol. 7, p. 186, pl. 31, figs. 14, 15.

—— **bicarinata** Beecher, 1884; 2d Geol. Survey Penn., vol. PPP, p. 16, pl. 2, figs. 3–5. Chemung.

—— **bicarinata** Etheridge, Woodward, and Jones, 1885; 3d Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 35.

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—— **interrupta** Etheridge, Woodward, and Jones, 1885; 3d Rept. Comm. Foss. Phyllopoda Pal. Rocks, p. 35.
—— **interrupta** Hall, 1888; Pal. New York, vol. 7, p. 185, pl. 31, figs. 7–12.
Turrilepas Woodward, 1865; Quart. Jour. Geol. Soc., vol. 21, p. 489.
—— **cancellatus** Hall, 1888; Pal. New York, vol. 7, p. 216, pl. 36, fig. 2. Corniferous.
—— [*Plumulites*] **devonicus** Clarke, 1882; Am. Jour. Sci., 3d series, vol. 24, p. 55, figs. 1, 2. Hamilton.
—— **devonicus** Hall, 1888; Pal. New York, vol. 7, p. 215, pl. 36, fig. 1.
—— **flexuosus** Hall, 1888; Pal. New York, vol. 7, p. 215, pl. 36, fig. 1. Corniferous.
—— **foliatus** Hall, 1888; Pal. New York, vol. 7, p. 218, pl. 36, fig. 15. Hamilton.
—— [*Plumulites*] **newberryi** Whitfield, 1882; Annals New York Acad. Sci., vol. 2, p. 217. Hamilton.
—— **newberryi** Hall, 1888; Pal. New York, vol. 7, p. 219, pl. 36, figs. 16–19.
—— **nitidulus** Hall, 1888; Pal. New York, vol. 7, p. 218, pl. 36, fig. 4. Hamilton.
—— **squama** Hall, 1888; Pal. New York, vol. 7, p. 217, pl. 36, figs. 5–8. Hamilton.
—— **tener** Hall, 1888; Pal. New York, vol. 7, p. 219, pl. 36, figs. 9–14. Hamilton.

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UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL, DIRECTOR

A REPORT OF WORK DONE

IN THE

DIVISION OF CHEMISTRY AND PHYSICS

MAINLY DURING THE

FISCAL YEAR 1888-'89

F. W. CLARKE, Chief Chemist

WASHINGTON
GOVERNMENT PRINTING OFFICE
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PREFACE.

The present bulletin represents work finished in the Division of Chemistry and Physics during the fiscal year 1888–'89, and resembles in general design and purpose its predecessors, Nos. 9, 27, 42, 55, and 60. It covers, however, only a part of the work actually accomplished, for some investigations are not yet completed, others will appear in special bulletins now in course of preparation, and many analyses will be published in forthcoming reports of the field geologists.

F. W. CLARKE,
Chief Chemist.

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WORK DONE IN THE DIVISION OF CHEMISTRY AND PHYSICS IN 1888-'89.

A THEORY OF THE MICA GROUP.

By F. W. Clarke.

Ever since its publication in 1878,[1] in spite of a few dissentient voices, Tschermak's theory of the mica group has been generally in vogue. Nevertheless, upon careful inspection, the theory seems open to serious objections. In brief, omitting details for the present, Tschermak regards the micas as made up of four fundamental molecules; to which the following formulæ are assigned:

1. $R'_6Al_6Si_6O_{24}$.
2. $Mg_{12}Si_6O_{24}$.
3. $H_8Si_{10}O_{24}$.
4. $F_{24}Si_{10}O_8$.

R′ stands obviously for K, Na, Li, or H; Mg is equivalent to Fe″, and aluminum may be replaced by ferric iron. The first of these formulæ represents fairly well the composition of normal muscovite and paragonite; the only objection to it being that, as used by Tschermak, it assumes the double atom of quadrivalent aluminum. Since it has been proved by Nilson and Petterson, Combes, Quincke, and others, that aluminum is truly trivalent, the formula should become $R'_3Al_3Si_3O_{12}$; which, as I have shown in several previous papers, may be regarded as a substitution derivative of normal aluminum orthosilicate.

The second, third, and fourth of Tschermak's formulæ represent hypothetical compounds, the second being a polymer of chrysolite, to which, in nature, some varieties of talc offer the nearest approximation. The third and fourth formulæ are analogous to no known substances, and are, moreover, improbable chemically. No mica, by itself, resembles in composition either of the three. One formula, then, corresponds to an observed mineral, while the others are purely speculative; a state of affairs which is not altogether satisfactory. Furthermore, the four formulæ represent as many distinct chemical types, whereas it would seem as if all the true micas should be reducible to one general form, under which their isomorphism would be more readily intelligible.

[1] Ber. Wien. Akad., vol. 78, p. 5. Zeitschr. Kryst., vol. 3, p. 122.

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There is still another objection to Tschermak's system of formulæ, which, if sustained by future investigation, will be fatal. Under his theory the ratio of oxygen to silicon in the micas can never exceed four to one; while the published analyses of micas often show values far higher, ranging in some cases nearly up to five. In certain instances, as Tschermak himself suggests, this excess of oxygen over the orthosilicate ratio may be due to water inclosed between micaceous laminæ; and in other cases it may indicate partial alteration. There are micas, however, in which neither of these explanations appears to be satisfactory, and the weight of evidence goes to show that the excess of oxygen is essential. If this be true, Tschermak's theory is so far inadequate, for to such micas it can not apply without serious modification. The question can only be settled experimentally, but at present the objection raised by it can not be ignored. Some of its details will be considered later.

Now, in order to conclusively replace Tschermak's theory by something better, two fundamental conditions must be satisfied. First, all micas, with the possible exception of the pseudomica, margarite, should be reducible to one general type of formula, which shall express all known relations equally well with the formulæ proposed by Tschermak. Secondly, hypothetical compounds must be so far as possible avoided, and admitted into consideration only when their assumption can be shown to be absolutely necessary. The chief difficulties to be overcome are the variations in the silicon-oxygen ratio, and the presence of fluorine in many common micas.

In a number of papers published during the past four years,[1] I have sought to show that all orthosilicates containing aluminum may be represented as substitution derivatives of the normal salt $Al_4(SiO_4)_3$. Muscovite can be so derived, theoretically, through the replacement of one aluminum atom by R'_3; and in many other cases we have equal simplicity of expression. The ferro-magnesian micas, the phlogopites, and the lepidolites, however, are less simply derived; and I have in certain cases suggested a linking together of two orthosilicate nuclei to the group $Al_2(SiO_4)_5$ in order to account for their formation. I am now inclined to believe, however, that all the true micas are referable to the same general type, and have discussed nearly one hundred published analyses from that point of view. If we take magnesium as a generic representative of the bivalent metals, and give univalent elements or groups the general symbol R, we can imagine the following derivatives of $Al_4(SiO_4)_3$ as easily possible:

1.

$$\begin{array}{l} \quad\;\; SiO_4 \equiv R_3 \\ Al - SiO_4 \equiv Al \\ \quad\;\; SiO_4 \equiv Al \end{array}$$

2.

$$\begin{array}{l} \quad\;\; SiO_4 \equiv R_3 \\ Al - SiO_4 \equiv R_3 \\ \quad\;\; SiO_4 \equiv Al \end{array}$$

3.

$$\begin{array}{l} \quad\;\; SiO_4 \equiv R_3 \\ Al - SiO_4 \equiv R_3 \\ \quad\;\; SiO_4 \equiv R_3 \end{array}$$

[1] Am. Jour. Sci., Nov., 1886, and Aug., 1887. Also, Am. Chem. Jour., vol. 10, p. 120 (March, 1888).

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4.

$$\begin{array}{l} \quad\quad SiO_4 \equiv MgR \\ Al \diagup\!\!\!\!\diagdown \\ \quad\quad SiO_4 \equiv Al \\ \quad\quad SiO_4 \equiv Al \end{array}$$

5.

$$\begin{array}{l} \quad\quad SiO_4 \equiv MgR \\ Al \diagup\!\!\!\!\diagdown \\ \quad\quad SiO_4 \equiv MgR \\ \quad\quad SiO_4 \equiv Al \end{array}$$

6.

$$\begin{array}{l} \quad\quad SiO_4 \equiv MgR \\ Al \diagup\!\!\!\!\diagdown \\ \quad\quad SiO_4 \equiv MgR \\ \quad\quad SiO_4 \equiv MgR \end{array}$$

To these we may add, as No. 7, the compound $Al_2(SiO_4)_6Mg_9$, the bivalent analogue of No. 3, and identical in type with it. Now, so long as we have only orthosilicate micas to consider, these seven formulæ cover all their variations in composition; provided that fluorine, when present, is represented either by $-Mg-F$ or $-Al=F_2$, univalent groups which are included under the general symbol R′. Most of the micas appear as intermediate mixtures of these presumably isomorphous types. No. 1 represents muscovite and paragonite, and No. 6 agrees tolerably with some phlogopites. No. 2 may be resolved into a mixture, in equal molecules, of No. 1 and 3; and similarly No. 5 may be regarded as composed of Nos. 4 and 6. Nos. 5 and 6, moreover, may be simplified into mixtures between 3 and 7, so that numbers 1, 3, 4, and 7 represent all the necessary relations. Even No. 4 is possibly superfluous.

So much for the normal orthosilicate micas. But in the lepidolites, phlogopites, and some muscovites, the oxygen silicon ratio is low; and in the lepidolites especially it approximates more or less closely to the metasilicate type. This order of variation is clearly established, while variations in the opposite direction, that is toward excess of oxygen, may be questionable. If, however, in any mica the oxygen can be properly in excess of SiO_4, that excess may be fairly regarded as present in the group $-Al=O$, which is obviously equivalent to $-Al=F_2$, and takes place with the latter as a part of R′. Examples of this kind are given in one of my former papers.[1] In all such cases the system of formulæ proposed above applies perfectly, and needs no qualification. The variations in R′ always fall within its limits.

The lower values for the silicon-oxygen ratios are explicable as follows: The polysilicic acid $H_4Si_3O_8$, which, like H_4SiO_4 is tetrabasic, is represented in nature by orthoclase and albite. In anorthite we have an orthosilicate, and its mixture with albite gives, as is well known to all mineralogists, the intermediate triclinic feldspars in which pseudo-metasilicate ratios often appear. $H_4Si_3O_8+H_4SiO_4=H_8Si_4O_{12}=4H_2SiO_3$. If we assume a similar state of affairs among the micas, and regard orthosilicates and polysilicates as isomorphously miscible, the lepidolites and other low oxygen micas are completely accounted for. We have then the same system of general formulæ for all micas, the normal salts $Al_4(SiO_4)_3$ and $Al_4(Si_3O_8)_3$ being the theoretical starting points for derivation. In every case the composition of a mica becomes reducible to the one general type, under the proposed theory of substitution. Representing the groups SiO_4 and Si_3O_8 by the common symbol X, the micas all fall within limits indicated by the formulæ $Al_3X_3R'_3$, and $AlX_3R'_9$. We may test this principle and the preceding formulæ by application to actual examples, taking the different micas group by group.

[1] Am. Jour. Sci., Aug., 1887, p. 131.

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MUSCOVITE.

This mica, the most typical and most abundant of all, is also the simplest chemically. It is best represented by formula No. 1, which, in its special application, becomes ordinarily $Al_3(SiO_4)_3KH_2$, with some variation in the ratio of K to H. In most cases muscovite contains small amounts of magnesia and ferrous iron; and if these are deducted, as shown in formula No. 6, the residue agrees still better with formula No. 1. Fluorine is often present in small quantities, and appears to vary in relation to hydrogen, being the lowest when the latter is high, and the reverse. Hence it is probable that the group AlF_2 replaces H rather than K. This is shown more clearly among the lepidolites, in which fluorine reaches a maximum, while the proportion of water is almost insignificant.

Some muscovites, however, vary from the normal compound in that they contain more silicon and less oxygen; thus approaching somewhat to lepidolite. These micas, which Tschermak has called "phengites," are represented by him as mixtures of $Al_6R'_6Si_6O_{24}$ with $H_8Si_{10}O_{24}$ in the ratio of three to one. It is simpler, however, to follow out the analogy offered by the feldspar group, and to assume the existence in muscovite of the isomorphous compound $Al_3(Si_3O_8)_3KH_2$. True, this compound has not been found by itself in nature, and so far its assumption is objectionable. But the compound $H_8Si_{10}O_{24}$ is also non-existent, is different in type from ordinary muscovite, and is not easily conceivable as a definite entity. The alternative which I offer for it is therefore, it seems to me, more philosophical and more satisfactory; and it accounts completely for all the oxygen variations in muscovite. For the sake of brevity, however, we may well retain the name of *phengite* in our vocabulary, and may speak of micas containing the Si_3O_8 group as more or less *phengitic*.

In order to show the method of discussion which I have employed, we may take the four muscovite analyses considered by Tschermak. A, muscovite from Bengal, analyzed by Blau; B, East Indies, by Sipöcz; C, Rothenkopf in the Zillerthal, by Sipöcz; D, Soboth in Steiermark, by Löbisch. Of these, C and D are phengites.

	A.	B.	C.	D.
SiO_2	45.57	45.71	45.87	48.76
Al_2O_3	36.72	36.57	30.86	29.91
Fe_2O_3	.95	1.19	5.70	4.24
FeO	1.28	1.07	1.69	.41
MgO	.38	.71	1.56	2.63
CaO	.21	.46	.23	.33
K_2O	8.81	9.22	9.07	6.83
Na_2O	.62	.79	.54	2.31
Li_2O	.19	.....	.....	.....
H_2O	5.05	4.83	4.60	4.60
F	.15	.12	.....	.....
	99.93	100.67	100.12	100.02

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Now, computing the molecular ratios in the usual way, uniting ferric oxide with alumina, ferrous iron and lime with the magnesia, and consolidating the alkalies under the general symbol R'_2O, we have the following empirical formulæ for the four micas:

A. $Al_{732}Mg_{30}R'_{220}H_{560}F_6Si_{759}O_{3027}$.
B. $Al_{732}Mg_{39}R'_{222}H_{536}F_6Si_{762}O_{3037}$.
C. $Al_{676}Mg_{66}R'_{212}H_{512}Si_{765}O_{2972}$.
D. $Al_{634}Mg_{78}R'_{220}H_{512}Si_{813}O_{3081}$.

Regarding the fluorine as AlF_2, and uniting it and the H with R′, these formulæ become, almost exactly:

A. $Al_{739}Mg_{30}R'_{783}(SiO_4)_{753}(Si_3O_8)_2$.
B. $Al_{729}Mg_{39}R'_{761}(SiO_4)_{753}(Si_3O_8)_3$.
C. $Al_{676}Mg_{66}R'_{724}(SiO_4)_{699}(Si_3O_8)_{22}$.
D. $Al_{634}Mg_{78}R'_{732}(SiO_4)_{642}(Si_3O_8)_{67}$.

Combining the two acid groups under the indiscriminate symbol X_f we have:

A. $Al_{739}Mg_{30}R'_{783}X_{755}$.
B. $Al_{729}Mg_{39}R'_{761}X_{756}$.
C. $Al_{676}Mg_{66}R'_{724}X_{721}$.
D. $Al_{634}Mg_{78}R'_{732}X_{699}$.

These are equivalent to the following mixtures of the isomorphous salts represented by the general formulæ 6, 3, and 1, in the fundamental system above cited:

A. $10\ AlX_3Mg_3R'_3 + 4\ AlX_3R'_9 + 238\ Al_3X_3R'_3$.
B. $13\ AlX_3Mg_3R'_3 + 239\ Al_3X_3R'^3$.
C. $22\ AlX_3Mg_3R'_3 + 218\ Al_3X_3R'_3$.
D. $26\ AlX_3Mg_3R'_3 + 7\ AlX_3R'_9 + 200\ Al_3X_3R'_3$.

In each case the final formulæ vary from the original ratios only to an extent which is ascribable to the minute residual errors of calculation. The new expressions conform perfectly to the evidence of analysis. Eight other muscovite analyses, similarly discussed, gave strictly similar and equally sharp results.

LEPIDOLITE.

In this species, the most phengitic of all the micas, we find little water, high fluorine, and a very notable proportion of lithia. It always occurs with muscovite, and commonly implanted upon the latter in such a way as to clearly indicate its later formation. In composition it is regarded by Tschermak as a mixture of $Al_6K_6Si_6O_{24}$ with $F_{24}Si_{10}O_8$, the former being about half replaced by the corresponding $Al_6Li_6Si_6O_{24}$, and the latter in part by $H_8Si_{10}O_{24}$. The objections to this interpretation have already been pointed out.

Under the new mode of interpretation, lepidolite becomes much simpler. In every case, if we eliminate traces of magnesia and iron, as was done under muscovite, the residue corresponds sharply to a mixture of the two molecules $AlX_3R'_9$ with $Al_3X_3R'_3$, X representing

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Si_3O_8 and SiO_4 indiscriminately. In the purest lepidolites these molecules are in the ratio 1 : 1, corresponding to $Al_2X_3R'_6$; but in general the second molecule is slightly in excess, due to small admixtures of normal muscovite. In the discussion of fourteen published analyses of lepidolite the ratio $Si_3O_8:SiO_4$ varies from 1 : 1 to 1 : 3; and the sum of $Li+AlF_2$ appears to be directly related to the proportion of Si_3O_8. In brief, expanding the general formulæ given above, typical lepidolite may be expressed by the two compounds $Al_3(SiO_4)_3KHLi$ and $Al(Si_3O_8)_3K_3Li_3(AlF_2)_3$ in equal molecules. All the variations may be accounted for by admixtures of muscovite, with sometimes a trivial amount of the magnesium or iron salt, No. 6, as an impurity.

For purposes of illustration, four of the lepidolite analyses may be considered in detail, as follows: E, from Rozena, by Berwerth,[1] F, Juschakova, by Rammelsberg;[2] G, Schüttenhofen, by Scharizer;[3] H, white lepidolite from Norway, Maine, by Riggs.[4]

	E.	F.	G.	H.
SiO_2	50.98	50.96	49.26	49.52
Al_2O_3	27.80	22.20	25.26	28.80
Fe_2O_3	.....	.....	.....	.40
Mn_2O_3	.....	5.38	.....	.....
MnO	.....	.....	.85	.07
FeO	.05	.....	.84	.24
MgO	.....	.....	.....	.02
CaO	.....	.....	.....	.13
K_2O	10.78	11.39	13.85	12.63
Na_2O	.....	.32	.35	.13
Li_2O	5.88	5.65	5.38	3.87
H_2O	.96	.....	1.76	1.72
F	7.88	8.58	5.68	5.18
P_2O_5	.05	.....	.....	.....
SnO_2	.....	.....	.06	.....
	104.38	104.48	103.29	102.71
Less O	3.32	3.61	2.38	2.18
	101.06	100.87	100.91	100.53

Disregarding trivial impurities, and computing the ratios as before, we have from these analyses the subjoined empirical expressions:

E. $Al_{347}K_{230}Li_{302}H_{106}(AlF_2)_{207}(Si_3O_8)_{181}(SiO_4)_{306}$.
F. $Al_{230}K_{252}Li_{376}(AlF_2)_{236}(Si_3O_8)_{212}(SiO_4)_{212}$.
G. $Al_{345}R''_{24}K_{250}Li_{358}H_{196}(AlF_2)_{149}(Si_3O_8)_{156}(SiO_4)_{353}$.
H. $Al_{434}R''_7K_{273}Li_{258}H_{192}(AlF_2)_{136}(Si_3O_8)_{141}(SiO_4)_{403}$.

Condensing, these become:

E. $Al_{347}R'_{935}X_{487}$.
F. $Al_{230}R'_{854}X_{424}$.
G. $Al_{345}R''_{24}R'_{963}X_{509}$.
H. $Al_{434}R''_7R'_{858}X_{544}$.

[1] See Tschermak's paper, l. c.
[2] Wiedemann's Annalen, vol. 7, p. 143.
[3] Zeitschr. Kryst., vol. 13, p. 467.
[4] Am. Jour. Sci., Nov. 1886.

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Whence we get, very nearly:

E. $70\ AlX_3R'_9 + 92\ Al_3X_3R'_3$
F. $71\ AlX_3R'_9 + 70\ Al_3X_3R'_3$.
G. $8\ AlX_3R''_3R'_3 + 75\ AlX_3R'_9 + 87\ Al_3X_3R'_3$.
H. $2\ AlX_3R''_3R'_3 + 52\ AlX_3R'_9 + 127\ Al_3X_3R'_3$.

Two other highly fluoriferous lithia micas, cryophyllite and zinnwaldite, may properly be considered here. For the former we have Riggs's analysis, and for the latter, analyses by Berwerth and Rammelsberg. From these analyses we get the following empirical formulæ: 1, Riggs, cryophyllite; 2 and 3, Berwerth and Rammelsberg, zinnwaldite.

1. $Al_{186}Fe''_{94}K_{255}Li_{324}H_{146}(AlF_2)_{176}(Si_3O_8)_{227}(SiO_4)_{185}$.
2. $Al_{239}Fe''_{186}K_{238}Li_{218}H_{102}(AlF_2)_{209}(Si_3O_8)_{151}(SiO_4)_{312}$.
3. $Al_{244}Fe''_{167}K_{242}Li_{224}H_{116}(AlF_2)_{200}(Si_3O_8)_{156}(SiO_4)_{306}$.

Condensing these formulæ they become:

1. $Al_{186}Fe_{94}R'_{904}X_{412}$.
2. $Al_{239}Fe_{186}R'_{765}X_{463}$.
3. $Al_{244}Fe_{167}R'_{782}X_{462}$.

Expanding again, these formulæ give:

1. $31\ (AlX_3Fe''_3R'_3) + 81(AlX_3R'_9) + 25(Al_3X_3R'_3)$.
2. 62 " +49 " +43 "
3. 56 " +53 " +45 "

The component molecules here correspond essentially to Nos. 6, 3, and 1 of the fundamental series, the last one in each expression being muscovite. Whether the separate components of R′ and X can be distributed with certainty among the several molecules is an outstanding question; but not, I believe, an unanswerable one.

PHLOGOPITE.

In order to ascertain the composition of this mica I have discussed the four analyses cited by Tschermak (l. c.), and three of Rammelsberg's.[1] All of these are fluoriferous, and all but one are phengitic, the exception in the latter case being the Edwards, N. Y., mineral, which Tschermak regards as somewhat altered. I have also considered the new phlogopite from Edwards, recently described by Penfield,[2] which is remarkable as being free from fluorine.

In general, phlogopite agrees closely with the formula $AlX_3Mg_3R'_3$, but there are often variations which are not easy to explain, and which are greater than can be accounted for by presumable errors of analysis. They may be due in part to impurities arising from the great alterability of the mineral; but I am inclined to trace the difficulties to other sources.

[1] Wiedemann's Annalen, vol. 9, p. 129. [2] Am. Jour. Sci. (3), vol. 36, p. 329.

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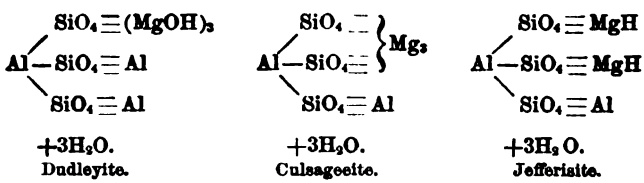
In order to satisfy the conditions of the formulæ proposed by me, it is necessary that the aluminum atoms, apart from AlF_2, shall be in number at least one-third of X; but in several phlogopites the alumina is too low to fulfill this requirement, and the difficulty is best obviated by assuming an MgF group in place of AlF_2. In Penfield's phlogopite, however, there is no fluorine, and yet the alumina is considerably—about two per cent—too low. If we suppose in his mineral, which came from a talc mine, a small admixture of talc, the residue agrees with the theoretical formula, X being wholly SiO_4; but if that impurity is absent we must assume that the mica differs from ordinary phlogopite by containing the group —Mg—OH instead of the usual MgF. The composition of the mineral then reduces to the uniform type. I am now disposed to believe that phlogopite differs from the other micas in that it contains these special groups MgF and MgOH, both as part of R′; but the supposition is not yet fully justified. It is, however, I think, susceptible of experimental investigation, and a laboratory research upon the problem is now being carried out under my direction. Apart from that, the supposition is strengthened by the composition of certain vermiculites, some of which have certainly been formed by the alteration of phlogopite. Three of these interesting minerals are represented fairly well by the subjoined formulæ, in which ferric iron, present in small quantities, has been reckoned with the alumina.



It is by no means certain that the vermiculites are so simple in composition or so definite as these symbols would seem to indicate; but the formulæ are decidedly suggestive, and they show how clearly the relations between the micas and their derivatives may be expressed.

THE FERRO-MAGNESIAN MICAS.

This group of micas, which includes biotite, lepidomelane, annite, haughtonite, siderophyllite, and other supposed species, is apparently quite complex. In place of magnesia, ferrous iron is often predominant; in the lepidomelanes, ferric iron replaces aluminum, and in forty-four out of the fifty-six analyses discussed, the oxygen was in excess of SiO_4. Only seven of these micas appeared to be phengitic; and only sixteen of the analyses reported fluorine in small quantities. In six instances AlO and AlF_2, were both absent.

For thirty-four of the micas in this group, formulæ could be easily computed upon the lines already followed; that is, in each case the

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composition was represented by a mixture of $AlX_3R''_3R'_3$ with $AlX_3R'_9$ and $Al_3X_3R'_3$, the second or third of these molecules being occasionally absent. Among the lepidomelanes there was an approximation to a distinctively muscovitic type; and in two cases formula No. 4, $Al_3X_3R''R$, seemed to apply. With each mica an attempt was made to determine the proportions of the several admixed molecules; but the results, although numerically conformable to the general theory, were not absolutely conclusive. The chief difficulty lay in the uncertainty attaching to the water determinations, upon which the question of oxygen excesses depends. Since water has a low molecular weight, a small error in its estimation becomes relatively large in the molecular ratios, and two sorts of errors are presumable: First, an excess of water may be inclosed mechanically in the material analyzed, and secondly, a determination by simple ignition is likely to be too low because of the oxidation of ferrous iron. If these errors occur together, they obviously tend to compensate each other; but either one alone seriously affects the co-efficient of R′, and appears in the ratio between $Al_3X_3R'_3$ and $AlX_3R'_9$.

In twenty-two of the fifty-six analyses, however, the symbol $AlX_3R''_3R'_3$ failed to account for all the bivalent metals, iron and magnesium. In these cases R″ was in excess of R′, and it became necessary to make use of formula No. 7, $Al_2(SiO_4)_6R''_9$. With the aid of this expression all the ferro-magnesian micas, without a positive exception, including the phlogopites, were resolvable into mixtures of $Al_3X_3R'_3$, $AlX_3R'_9$, and $Al_2X_6R''_9$. Upon this basis formula No. 6 becomes useless, for $AlX_3Mg_3R'_3$ is evidently equivalent to a mixture, in equal molecules, of $AlX_3R'_9$ and $Al_2X_6Mg_9$. All micas, then, so far as the analyses are authentic, may be represented as mixtures of the molecules 1, 3, and 7, these being symbols of one and the same general type. The magnesium (or ferrous) salt thus assumed, moreover, is not absolutely hypothetical; for, with six molecules of water of crystallization added, it approximates to certain individuals of the chlorite group. Some examples of penninite, for instance, approach rather closely to the composition $Al_2(SiO_4)_6Mg_9 . 6H_2O$, which requires 38.71 of silica, 10.97 alumina, 38.71 magnesia, and 11.61 water. We have thus a clue to the constitution of the chlorites, by means of which they may be brought into simple relation with the micas. This problem is now under investigation, and I can only state as a probability that most of the chlorites, if not all, may be represented as mixtures of three fundamental molecules, $Al_2X_6R''_9, 6H_2O$; $AlX_3R''_3H_3, 3H_2O$, and $Al_2X_3(MgOH)_6$. I hope to speak more positively upon this subject before long; at present I need only point out that two of these molecules are simple hydrates of Nos. 6 and 7, while the third is covered by the general symbol No. 3, in which R'_6 becomes $(MgOH)_6$. The easy alterability of garnet, $Al_2(SiO_4)_3R''_3$ into mica and chlorite, is a suggestive bit of evidence bearing upon these expressions.

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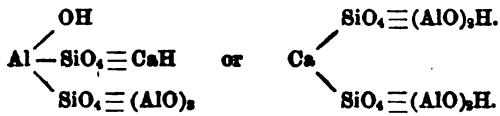
MARGARITE.

Whether this species is to be considered as a true mica or not, is perhaps an open question. Its composition is relatively simple, and is represented by the empirical formula $H_2CaAl_4Si_2O_{12}$. Structurally, this may be written in two distinct ways, as follows:

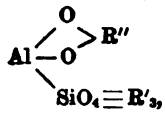


The first of these symbols derives the compound from the normal aluminum salt, and indicates a similarity of type with the micas proper. The second assumes a normal calcium salt as the point of derivation; and I am unable as yet to assign a distinct preference to either expression. A careful study of the genesis and associations of margarite may determine which of the two formulæ is the better. Possibly the occurrence of the mineral in such mixtures as euphyllite, and the probable existence of a similar barium salt in œllacherite points to the first of the two formulæ as the better. The common occurrence of margarite with diaspore also points in the same direction. Corundophilite, which occurs associated with both margarite and diaspore, also reduces to a type resembling the first margarite formula.

THE CLINTONITE GROUP.

These minerals, the so-called "brittle micas," have also been discussed by Tschermak,[1] who includes under this heading seybertite, brandisite, xanthophyllite, chloritoid, masonite, ottrelite, sismondine, and sapphirine. Physically, they are closely related to the micas proper, and to margarite in particular; but chemically they are much more basic. The first three species Tschermak regards as mixtures of the hypothetical compounds $H_2CaMg_4Si_3O_{12}$ and $H_2CaMgAl_6O_{12}$; to chloritoid he assigns the composition $H_2Si_2Fe''_2O_7, \times H_2Al_4O_7$, and sapphirine he represents by the formula $Si_2Mg_2O_6 + Al_6Mg_2O_{11}$.

Using the analyses cited by Tschermak, I find that all these minerals, with the possible exception of sapphirine, may be represented by the general expression



which is clearly and directly related to the formulæ already assigned to the micas and to margarite, and in which the mode of union of R'' with Al, when R''=Mg, suggests the common association of members of this group with spinel. In seybertite we have a mixture of

[1] Zeitschr. Kryst., vol. 3, p. 496.

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$AlO_2R''SiO_4(MgOH)_3$ with $AlO_2R''SiO_4(AlO)_3$, R″ being partly Ca and partly Mg. In brandisite we have a similar constitution, with about one-fourth of R″ replaced by H_2. In chloritoid, R″=Fe and $R'_3=H_2(AlO)$; and sismondine is similar, with R'_3 possibly replaced in part by Al. The compound $AlO_2MgSiO_4(AlO)_3$, found in seybertite, is a rough approximation to sapphirine, which mineral possibly has this composition plus some impurities as yet unidentified. A wider range of analyses is needed in order to establish these formulæ completely; but they seem to have distinct advantages over the formulæ proposed by Tschermak.

CONCLUSIONS.

All the micas, vermiculites, chlorites, margarite, and the clintonite group may be simply represented as isomorphous mixtures, every constituent being a substitution derivative of normal aluminum polysilicate or orthosilicate. To the latter compound a structure may be assigned somewhat different in form from the one I have chosen, without affecting in any notable way the general system adopted. Upon this basis all the minerals named are reducible to the same general type, which accounts for observed isomorphisms, and for the relations of the micas to other species, with fewer assumptions of hypothetical compounds than are necessary under other known schemes of interpretation. In most cases the evidence is clear, direct, and conclusive; in other cases, few in number, it is at present somewhat obscure. It may be claimed, without extravagance, that the formulæ have the merit of suggestiveness, and that they form a scientific basis for future research.

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A PLATINIFEROUS NICKEL ORE FROM CANADA

By F. W. Clarke and Charles Catlett.

During the autumn of 1888 we received, through two different channels, samples of nickel ores taken from the mines of the Canadian Copper Company at Sudbury, Ontario. From one source we obtained two masses of sulphides, to be examined for nickel and copper; from the other source came similar sulphides, together with a series of soil and gravel-like material, seven samples in all. In the latter case an examination for platinum was requested, and in five of the samples it was found, the gravel above mentioned yielding 74.85 ounces of metals of the platinum group to the ton of 2,000 pounds. At the outset of the investigation we were decidedly incredulous as to the existence of platinum in such ores; but the discovery of sperrylite by Mr. Wells in material from the same mines gave our work a wholesome stimulus, and the assays were carefully carried through.

The sulphide ores submitted to us from Sudbury were all of similar character. They consisted of mixed masses, in which a gray readily tarnishing substance was predominant, with some chalcopyrite, possibly some pyrite, and a very little quartz. Two samples were examined in mass; one gave 31.41 per cent of nickel with a little copper, the other gave 35.39 per cent of nickel and 5.20 of copper. The nickel mineral itself proved to be a suphide of nickel and iron, and as ores of that composition are not common, it was thought desirable to examine the substance further.

As above stated, the nickel mineral is the predominating constituent of the masses submitted for examination. It is steel gray, massive, and exceedingly alterable in the air, and its specific gravity, determined by pycnometer, is 4.541. An analysis of carefully selected material gave the following results:

Ni	41.96
Fe	15.57
SiO_2	1.02
Cu	.62
S	40.80
	99.97

Neither cobalt nor arsenic could be detected.

The foregoing figures work out sharply into the ratio R : S :: 4 : 5; and approximately into the formula Ni_3FeS_5. If we deduct silica, together

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with the copper reckoned as admixed chalcopyrite, and recalculate the remainder of the analysis to 100 per cent, we have the following figures:

	As found.	Calc. as Ni_3FeS_5.
Ni	43.18	44.6
Fe	15.47	14.4
S	41.35	41.0
	100.00	100.0

In short, the mineral has the composition Ni_4S_5, with *about* one-fourth of the nickel replaced by iron. The only known species with which this agrees is Laspeyres's polydymite, of which the Sudbury mineral is evidently a ferriferous variety. What relations it may bear toward beyrichite, pyrrhotite, etc., is as yet a matter of considerable uncertainty. Probably in most cases the nickeliferous constituent of pyrrhotite is millerite, but other sulphides, like the polydymite, may perhaps occur also.

The polydymite which was selected for the above analysis came from the mass in which, in average, 35.39 Ni and 5.20 Cu had previously been found. The mass weighed several kilograms, and was remarkably free from quartz. The same mass, with two smaller pieces resembling it, were also examined for platinum, by the following method: One assay ton of the finely ground ore was treated with nitric acid until all or practically all of the sulphides had been dissolved. The dried residue was then assayed in the usual manner; except that, to facilitate cupellation, a little pure silver was introduced into the lead button. From the final bead the silver was dissolved out by sulphuric acid, leaving the platinum in a finely divided gray powder. The latter dissolved easily in aqua regia, and gave all the reactions needful to identify it thoroughly. The results were as follows, "A" representing the large mass in which the polydymite was determined:

	Per cent.
A, 2.55 ounces Pt to the ton, or	0.0087
B, 1.8 ounces Pt to the ton, or	.0060
C, 7 ounces Pt to the ton, or	.0240

That the metal weighed was nearly all platinum is certain; but it may have contained small amounts of other metals of the same group. The material separated was not sufficient to warrant a search for the rarer associates of platinum. Probably the platinum exists in the ore as sperrylite, although this point was not proved. The amount of platinum in the mass most thoroughly examined would require, to form sperrylite, only about 0.007 per cent of arsenic, which is too small a quantity for detection by ordinary analysis. That platinum should exist in appreciable quantities in an ore of such character is something quite extraordinary. Whether it could be profitably extracted is an open question.

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A NEW OCCURRENCE OF GYROLITE.

By F. W. Clarke.

In the autumn of 1888, during a visit to the New Almaden Quicksilver Mine in California, Dr. D. T. Day, of the U. S. Geological Survey, was shown specimens of a mineral which was locally supposed to be white fluor-spar. It occurred in well-developed crystals lining crevice veins in the mine, and was easily recognizable as apophyllite. Dr. Day secured a good series of the specimens, and finally turned them over to me for examination. The largest crystals were about two centimeters in diameter, and fairly transparent, and grew out of crystalline masses of considerable thickness, the exposed definite faces nearly meeting at the center of the seam or vein. All of the specimens were saturated with bituminous matter, but except for that staining they were quite colorless.

In several of the specimens received the wall of the seam was distinctly shown, and between it and the crystalline apophyllite there was a fibrous layer from one to three centimeters in thickness. That layer was also colorless, except for bituminous staining, and on account of its relations to the apophyllite it appeared to deserve investigation. A sufficient quantity of the material having been selected, it was digested for about twenty-four hours with ether in order to cleanse it from bitumen, and then analyzed. I give the result in comparison with How's figures for a Nova Scotia gyrolite:

	Clarke.	How.
H_2O	14.60	15.05
SiO_2	52.54	51.90
Al_2O_3	0.71	1.27
Fe_2O_3		.....
CaO	29.97	29.95
MgO	.....	0.08
K_2O	1.56	1.60
Na_2O	0.27	.....
F	0.65	.....
	100.30	99.85
Less O	0.27	.....
	100.03	.....

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It will at once be seen that the two analyses, except for the small amount of fluorine, coincide quite sharply, and establish the New Almaden mineral as gyrolite. The Nova Scotian gyrolite is also associated with apophyllite, from which species How supposed it to be derived.[1] In the present instance, however, the relative position of the two minerals in the vein suggests that the gyrolite is the older; and that the apophyllite may have been formed from it by a partial solution and redeposition of its material through the agency of waters containing alkaline fluorides. The gyrolite is obviously not absolutely pure, but it agrees approximately with the formula $Ca_2Si_3O_8 . 3H_2O$. Its chemical structure and relations to apophyllite are not altogether clear.

[1] Am. Jour. Sci. (2), vol. 32, p. 13.

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ANALYSES OF THREE DESCLOIZITES FROM NEW LOCALITIES.

By W. F. Hillebrand.

1. MAYFLOWER MINE, BALD MOUNTAIN MINING DISTRICT, BEAVERHEAD COUNTY, MONT.

Through Messrs. W. H. Beck and George E. Lemon, of Washington, D. C., was received about a year ago for examination a large lump of friable, uncrystallized material, having a dull yellow to pale orange color, and consisting chiefly of a vanadate, but carrying a large percentage of gangue. Two samples as pure as could be selected from different parts of the lump were analyzed with the following results:

	I.	II.	Mean.	Molecular ratios.		
PbO	56.02	55.84	55.93	.2508		
CuO	1.16	1.13	1.15	.0145	.4718	4.02
FeO	0.70	0.70	0.70	.0097		
ZnO	15.96	15.91	15.94	.1968		
V_2O_5	.....	20.80	20.80	.1140		
As_2O_5	0.32	.....	0.32	.0014	.1173	1.00
P_2O_5	0.27	.....	0.27	.0019		
H_2O	4.37	4.36	4.37	.2428	.....	2.07
SiO_2	0.20	0.16	0.18			
CaO	0.10	.....	0.10			
MgO	0.06	.....	0.06			
			99.82			

From I 27.62 per cent of gangue insoluble in cold dilute nitric acid has been deducted, and from II 22.20 per cent; manganese was present in the gangue in small quantity, apparently as pyrolusite, but it was not dissolved by the acid. The insoluble portion was found also to retain very small quantities of lead and zinc, which were estimated and included in the analysis as probably belonging to the vanadate. The water had to be estimated indirectly by deducting from the total amount of water afforded by the dried mixture of vanadate and gangue that belonged to the latter alone, which was found as follows: The mixture, dried at 100° C., was dissolved in cold dilute nitric acid, and the insoluble matter collected in a Gooch crucible was dried at the same temperature and then ignited. The loss on ignition gave the water in

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the gangue, there being no ferrous iron in the latter to influence the result. The traces of SiO_2, CaO, and MgO may be neglected as probably derived from the gangue. The water, it will be noticed, is double that required by descloizite, $R_2(OH)VO_4$, but in view of the liability to error inherent in the method of water estimation employed, this is not deemed sufficient cause for separating the mineral from descloizite, although the close agreement of the two water determinations, made as they were on samples containing different proportions of gangue, would indicate the correctness of the formula $2[R_2(OH)VO_4]+H_2O$.

Other specimens have since been received from the above-named persons in which the earthy vanadate was associated sometimes with compact cerussite and galena in process of alteration. A dull reddish substance which constituted a part or even the whole of some lumps contained, besides silica, iron and some antimony in an oxidized condition, but carried little or no vanadium.

Prof. F. A. Genth has already called attention[1] to the occurrence of vanadinite and probably of descloizite in the Bald Mountain mine, Beaverhead County, Mont. His specimens, however, showed the supposed descloizite as a pale brownish crystalline coating on yellow ferruginous quartz, whereas the present mineral shows no evidence of crystalline structure.

2. COMMERCIAL MINE, GEORGETOWN, GRANT COUNTY, N. MEX.

This is one of the most interesting occurrences of descloizite known, because of the extreme brilliancy of coloring of the mineral. The ore bodies in the Commercial mine, as well as in the adjoining MacGregor and Naiad Queen mines, occur in limestone immediately under an overlying slate, and appear to narrow in depth where certain eruptive dikes cut through the lime, as Mr. MacIntosh, foreman of the Commercial mine, informed me. The absence of the superintendents of the several mines and the very brief visit I was forced to make prevented obtaining more certain and detailed information.

In places where the rock is most fractured and crushed the descloizite appears in greatest quantity and finest condition as an incrustation on quartz, often covering large surfaces, and in color varying from yellow through all shades of orange-red to deep reddish brown, the last-named colors predominating. The black color so frequent in descloizite from Lake Valley, N. Mex., caused by a superficial coating or admixture of pyrolusite, is, so far as my observation extended, wanting, hence specimens from Georgetown are likely to be much sought after for their showy appearance. A specimen in one of the banks at Silver City, N. Mex., taken from one of the Georgetown mines, resembled a stalactite in form. It was probably fully three feet in height by six to eight inches or more in diameter, and was deep reddish brown in color.

[1] Proc. Am. Phil. Soc., 1887, vol. 24, p. 38.

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The incrustations are for the greater part distinctly crystalline and are generally made up of aggregates of more or less globular forms of a size ranging from microscopic to a diameter of one or two millimeters. Each of these is composed of a great number of apparently flat crystals, intergrown, and projecting sufficiently from the surface to give brilliant reflections when observed under the lens, and to the naked eye a frosted appearance where the globular growths are largest. The richest reddish brown color is always coincident with this development in size. The globular character changes frequently to acicular. In such cases the incrustation seems to have originally formed on bunches of radiating acicular, almost colorless, vanadinite, which frequently appears thus coating the quartz and running under the descloizite incrustations. Sometimes the vanadinite has entirely disappeared, and then there may be a hollow through the center of the descloizite needle.

The occurrence of vanadate of lead in the MacGregor mine at Georgetown has been noticed by Professor Genth (l. c., p. 38). The specific gravity of the mineral was not determined; the hardness is about 3.5; the color of the powder is orange-yellow. An analysis gave the following results after deducting 11.91 per cent of insoluble matter, almost entirely quartz:

		Molecular ratios.			
PbO	56.01	.2512			
CuO	1.05	.0132	.4843	.4788	4.12
FeO	0.07	.0010			
ZnO	17.73	.2189			
V_2O_5	20.44	.1119			
As_2O_5	0.94	.0041	.1178	.1162	1.00
P_2O_5	0.26	.0018			
H_2O	2.45	.1361	.....	.1361	1.17
Cl	0.04	.0011			
SiO_2	1.01				
CaO	0.04				
MgO	0.03				
	100.07				

The third column of molecular ratios gives those values after allowing for admixed vanadinite calculated on the basis of the chlorine found. A further correction has probably to be made for an admixed soluble hydrous (zinc ?) silicate, which might make the ratio approximate more closely to 4 : 1 : 1.

3. LUCKY CUSS MINE, TOMBSTONE, COCHISE COUNTY, ARIZ.

Mr. W. F. Staunton, superintendent of the Tombstone Mining and Milling Company, and Mr. Frank C. Earle, assayer at Tombstone, kindly placed at my disposal for examination specimens of a vanadium mineral the identity of which had not been established. It was found

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in the Lucky Cuss mine as an incrustation, sometimes half an inch thick, on quartz, showing more or less botryoidal surfaces of an indefinable dull greenish color. On a fractured surface the color is brown; the luster is resinous; the structure granular, only occasionally diverging fibrous; the hardness 3.5; the specific gravity of sample analyzed containing a little impurity, 5.88 at 19° C.; color of powder lemon-yellow. Analysis gave the following results after deducting 0.67 per cent of insoluble matter:

		Molecular ratios.			
PbO	57.00	.2556			
CuO	11.21	.1412	.4485	.4385	3.93
FeO	Trace.	.....			
ZnO	4.19	.0517			
V_2O_5	19.79	.1084			
As_2O_5	1.10	.0048	.1145	.1115	1.00
P_2O_5	0.19	.0013			
H_2O	2.50	.1389	.....	.1389	1.25
Cl	0.07	.0020			
SiO_2	0.80				
CaO	1.01				
MgO	0.04				
K_2O	0.10				
Na_2O	0.17				
CO_2	0.82				
	98.99				

The low total is probably owing to a loss of zinc during analysis. Calcite was present as an impurity, and as the CO_2 just suffices for the CaO and MgO these are rejected in considering the composition of the vanadate. The figures in the third column of molecular ratios are found by allowing for probably admixed vanadinite calculated from the chlorine found. In another specimen a qualitative test for chlorine indicated a greater admixture of vanadinite. As in the case of the descloizite from Georgetown, N. Mex., previously described, a further allowance has perhaps to be made for a soluble hydrous silicate. There can be no doubt that the general formula for the vanadate is that of descloizite.

In almost every respect this mineral resembles, so far as the published descriptions allow of judging, the descloizite of Penfield,[1] the cupro-descloizite of Rammelsberg,[2] and the ramirite of de Leon,[3] perhaps also the tritochorite of Frenzel,[4] to the similarity of which with his variety of descloizite Penfield draws attention in his paper. Professor Genth's surmise (l. c., p. 39) of the specific identity of all these sub-

[1] Am. Jour. Sci. (3), vol. 26, p. 361.
[2] Monatsb. Berl. Acad., 1883, p. 1215.
[3] La Ramirita, nueva espécie mineral, Mexico, 1885.
[4] Tschermak's Min. and Petr. Mitth., vol. 3, p. 506, 1880, vol. 4, p. 97, 1881.

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stances seems highly probable. Characteristic of the present variety is the greater replacement of the lead-zinc vanadate—true descloizite—by the isomorphous lead-copper vanadate and the lessened tendency toward a fibrous structure, which in the other varieties described seems to be a decidedly pronounced feature. Possibly this last characteristic of the Tombstone mineral, if it be not accidental in view of the few specimens (three) examined, is a condition of the first.

According to Rammelsberg,[1] the lead-copper vanadate corresponding to the lead-zinc vanadate (descloizite) is mottramite or psittacinite, though it seems not improbable that it may be the chileite of Dana's Mineralogy. Domeyko's analyses,[2] which led Kenngott to ascribe the above name to the Chilian mineral, show a deficiency of 2.5 and 2.8 per cent, which may very well be V_2O_5. At all events, a recalculation of his analyses based on this assumption leads to a proportion for $PbO+CuO : V_2O_5 : H_2O$ of nearly 4 : 1 : 1.

In view of the well defined character of all these highly cupriferous varieties of descloizite it would be well to designate them once for all by some distinctive name. Tritochorite would have precedence if the substance to which that name has been given is really identical with the others, but Rammelsberg's cupro-descloizite is more appropriate as indicating at once the relationship to descloizite, and I would suggest that it be henceforth used for all cupriferous descloizites showing the physical characteristics of the mineral above described.

NOTE.—Since the foregoing was written there has appeared in the Bull. Soc. Franc. Min., Feb., 1889, p. 38, a paper by F. Pisani, in which he gives another analysis of the Mexican cupro-descloizite and discusses briefly the relations of various vanadates. The essential identity of all the above-enumerated cupriferous lead-zinc vanadates, with the addition of another—schaffnerite, concerning which I have been unable to find any further reference in mineralogical literature—is therein upheld, and the suggestion of Penfield regarding the possible identity of tritoshorite and cupro-descloizite is confirmed by Frenzel himself, who is quoted as writing to Professor DesCloizeaux that he had not thought it necessary to consider as an essential constituent the two per cent of water which he had found in tritochorite.

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[1] Chemische Natur der Mineralien, p. 32.

[2] Ann. d. Mines, IV, vol. 14, 1848, p. 150; Phil. Mag., III, vol. 34, 1849, p. 395.

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A NEW METEORITE FROM MEXICO.

By J. Edward Whitfield.

While in Mexico during the summer of 1888, Prof. H. A. Ward, of Ward and Howell, Rochester, N. Y., obtained an undescribed mass of meteoric iron weighing 33.0 kilos.

The meteorite was found on a peak of the Sierra de San Francisco, called La Bella Roca, in front of Santiago Papasquiaro, in the State of Durango. The date of its discovery and the name of the finder are unknown.

The composition of the metallic portion does not differ materially from that of other meteoric irons, as the following analysis will show:

Fe	91.48
Ni	7.92
Co	0.22
P	0.21
S	0.21
C	0.06
	100.10

A feature of the meteorite is the presence of large, deep pittings on one side; these are a little greater in diameter just below than immediately at the surface and each one has a little substance left at the bottom, which evidently is the remains of what originally filled the cavities. I succeeded in breaking from the bottom of one pitting material sufficient to determine its nature. It proved to be troilite as the analysis will show:

NiS 2.13, FeS 85.27, Fe 9.37.

The exposed surface of the troilite was greatly decomposed; this portion gave by analysis the following figures:

NiS 2.07, FeS 37.51, Fe_2O_3 37.80. Moisture, 19.85.

This decomposition gives grounds for the idea that the deep pittings were formed by the removal of troilite nodules, partly while the mass was hot and partly by the subsequent weathering.

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There are nodules of troilite throughout the entire mass of the meteorite, but none are removed so as to form pittings, on any other part of the surface but the side which is supposed to have been forward.

The mass is deeply furrowed and all the furrows tend away from the side containing the pittings.

Slices of the meteorite, when etched, show rather coarse Widmanstättian figures and also dark diagonal bands of troilite.

From the locality in which this meteorite was found it is but proper that it should be called "La Bella Roca."

I am indebted to Messrs. Ward and Howell for the material for examination and the privilege of description.

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DUMORTIERITE FROM HARLEM, N. Y., AND CLIP, ARIZ.

By J. S. Diller and J. E. Whitfield.

In 1887 Dr. R. B. Riggs published a description, including a chemical analysis, of "the so-called Harlem indicolite," which was regarded as probably a new boro-silicate. The notice led to correspondence with Prof. E. S. Dana, who identified the mineral as dumortierite, and kindly sent us some of the original dumortierite from near Lyons, France, for comparison.

The physical properties of the Harlem dumortierite agree very closely with those mentioned by Bertrand,[1] Gonnard,[2] and Damour.[3] Crystals are very rare. An imperfect one[4] has been observed with $a(\infty P\infty)$ and $m(\infty P)$ equally developed. Both planes are striated parallel to the vertical axis. Indistinct reflections allowed only approximate measurement $am=152°$, and therefore $mm=124°$. Obtuse terminal planes rarely observed on embedded crystals..

Cleavage parallel to a is distinctly developed so that when the mineral is crushed and examined under a microscope cleavage plates may be found which show an obtuse bisectrix lying parallel to $b(\infty\breve{P}\infty)$. Cross fractures occasionally yield basal sections which may be made to exhibit an acute bisectrix. Extinction always takes place parallel to the vertical axis and the mineral is evidently rhombic.[5] In cross-sections imperfect cleavage is rarely seen parallel to some prismatic plane. Polysynthetic twinning is very common parallel to b as well as to other planes in the prism zone. Liquid inclusions and long tubular cavities parallel to the vertical axis are abundant. Hardness $=7$ and specific gravity slightly above 3.265.

The rock in which the dumortierite occurs at Harlem is the pegmatoid

[1] Bull. Soc. Min. d. France, vol. 3, 1880, p. 171, and vol. 4, 1881, p. 9.

[2] Bull. Soc. Min. d. France, vol. 3, 1881, p. 2.

[3] Bull. Soc. Min. d. France, vol. 4, 1881, p. 6.

[4] It was kindly loaned to us by Mr. R. T. Chamberlin, of New York. Our thanks are also due to Mr. George F. Kunz for the material he so generously furnished for this investigation. It was collected along Fourth avenue at One hundred and twentieth and One hundred and twenty-second streets, as well as near Fort George, a new locality of the same district.

[5] My observations, noted in Mr. Riggs's paper, already referred to, were very hastily made with imperfect apparatus, and published before I had an opportunity for their revision.—J. S. Diller.

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portion of a biotite gneiss. These coarse vein-like parts are composed of quartz with both red and colorless orthoclase, some plagioclase and tourmaline. The other portions of the rock contain much biotite and garnet. The fibers of dumortierite are sparingly scattered through the quartz in the coarse granular rock. A few were observed penetrating plagioclase. The thin, thread-like fibers are occasionally so small as not to be distinctly dichroic, but they are intermingled and connected with larger dichroic fibers by every intermediate gradation in size, so that an observer at once regards them all as the same mineral. They sometimes closely resemble the trichitic forms in granitic quartz, which Dr. G. W. Hawes[1] and many others following his suggestion regarded as rutile.

The presence of tourmaline in the rock at Harlem was not at first recognized. It is so intimately associated with the dumortierite that they can not be easily separated. Their pleochroic phenomena, however, are so unlike that they can be readily distinguished under a polarizing microscope. The presence of tourmaline renders the results of Mr. Riggs's analysis less trustworthy. By means of the Klein solution and an electro-magnet the tourmaline was separated from the dumortierite. The .217 gram of the latter thus obtained was analyzed with the following result.[2] Only the smallest trace of B_2O_3 was observed.

SiO_2 31.44 Al_2O_3 68.91

Fortunately, at the time it became particularly desirable to obtain a larger quantity of dumortierite for analysis a collection of minerals was sent by Mrs. C. A. Bidwell from Clip, Yuma County, Arizona, to the National Museum for identification. Among them Prof. F. W. Clarke noticed a blue mineral, which proved to be dumortierite. It is finely fibrous and so abundant as to give color to the rock, which is composed chiefly of granular quartz. A few grains of magnetite and limonite are the only other minerals intermingled with the quartz and dumortierite, so that it seems an easy matter by means of a heavy solution and an electro-magnet to obtain the latter mineral for chemical analysis. The results are given under I, below.

These figures appear to show the material analyzed to be impure, and it was thought advisable to obtain more of the rock and endeavor to separate the dumortierite as far as practicable from all impurities. Mrs. C. A. Bidwell kindly furnished a sufficient amount of much better material, in which the only mineral associated with the dumortierite was quartz. As dumortierite is not acted upon by hydrofluoric acid; the rock, after being crushed to small particles, was digested in this acid for a length of time sufficient to decompose most of the quartz. The mass was then washed with water, dried, and any quartz that might still remain separated by Thoulet's solution. After thorough washing

[1] Mineralogy and Lithology of N. H., 1878, p. 45.

[2] The chemical work for this paper was done by Mr. Whitfield.

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the material was examined with the aid of a microscope and found to be free from gangue. Having been ground exceedingly fine and dried at 104° C. for about three hours, the mineral was analyzed with the following results (II):

	I.	II.
SiO_2	31.52	27.99
Al_2O_3	63.66	64.49
CaO	trace.	.....
MgO	.52	trace.
Na_2O	.37	.....
K_2O	.11	.....
B_2O_3	2.62	4.95–4.98
P_2O_5		0.20
Ignition	1.84	H_2O 1.72
	100.14	99.35

Analysis II shows less impurity than the first specimen analyzed. These results indicate either that dumortierite is not a simple silicate of aluminum as stated by Damour;[1] or else that the material analyzed was a mixture of dumortierite with some other compound.

If we assume the formula of Damour to be correct and estimate all the SiO_2 in the analysis as belonging to the formula $Al_8Si_3O_{18}$, then there will be left unaccounted for a small amount of Al_2O_3, H_2O, and B_2O_3, and these are present in the proportions represented by the formula $AlB_3O_6 . 2H_2O$. If this mode of interpretation be correct, then the mineral from Arizona corresponds approximately to the formula $3Al_8Si_3O_{18}.AlB_3O_6 . 2H_2O$ which requires Al_2O_3=65.2 per cent; SiO_2=27.6 per cent; B_2O_3=5.4 per cent; H_2O=1.8 per cent, agreeing quite closely with the actual analysis. A borate of aluminum corresponding to the above formula is, we believe, not actually known, and concerning its properties nothing can be predicted. If it exists it is certainly remarkable that it should withstand the treatment with hydrofluoric acid which the dumortierite received during the process of purification.

We are greatly indebted to Mrs. C. A. Bidwell for the supply of material for investigation, which at the cost of much personal labor she so liberally furnished.

[1] Bull. Soc. Min. de France, vol. 4, p. 6.

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CHEMICAL ACTION BETWEEN SOLIDS.[1]

By William Hallock.

In a note on a new method of forming alloys published some time ago,[2] I suggested some additional experiments which I intended to make, and I now give the results thus far obtained. Unfortunately, other work prevents my continuing the investigation at present.

Inasmuch as the method and principle[3] seemed well established where metals were used to produce alloys, an attempt was made to include some chemical reactions in the list. The most natural cases were the freezing mixtures where solid reagents are used. In order to surely have both constituents in a decidedly solid state the experiments were performed in a vessel cooled to a temperature of minus 10° or 12° C., care being always taken to leave the reagents in the vessel long enough for them to assume a temperature decidedly below zero Centigrade. Under these conditions a crystal of rock salt (NaCl) and a piece of clean, dry ice were gently brought in contact, lying side by side on a watch glass. Of course the result was the solution of salt, but old as this experiment may be, it appears here in a new connection, as an example of the union of two solids below the melting point of either, but above that of the product. The piece of ice was frozen to the glass and during the operation the crystal was drawn several millimeters across the glass, doubtless by capillarity, as the solution ran out at the bottom of the surface of contact as fast as it formed, the attraction being sufficient to move a crystal several grams in weight.

Similar experiments were performed with sodium and potassium, nitrate potassium, calcium and ammonium chloride, and sodium and potassium hydrate, with a similar result in all cases. These are all well known results, but wherein do they differ from the new method of forming alloys? This question suggests another. Are the metals combining to form an alloy in the new way a freezing mixture? A thorough

[1] This paper was read in part before the Phil. Soc. of Washington, D. C., October 13, 1888, and appeared in full in the Am. Jour. Sci., vol. 37, 1889, p. 402.

[2] W. Hallock, Zeitschr. f. Phys. Chem., vol. 2, 1888, p. 6. Science, vol. 11, 1888, p. 265.

[3] O. Lehmann, Wiedemann Ann., vol. 24, 1885, p. 5, suggested the theoretical possibility of producing an alloy in this way. I had overlooked his paper until recently. Mr. Lehmann, however, evidently did not consider it possible to fulfill the necessary conditions and did not try the experiment.

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investigation of the question would require more complicated experiments than I had time to perform. One test, however, is very simple, that with potassium and sodium.

Into a small porcelain crucible weighing 15 grams and containing about an equal weight of petroleum were placed pieces of the two metals, about 3 grams of each. One junction of a thermo-element was forced into the piece of potassium and gave its temperature accurately. After the whole had assumed the room temperature, clean faces of the two metals were brought into contact, the liquefaction began, and *the temperature immediately fell.* It required about two hours to complete the liquefaction and about one and a half hours to attain the minimum of temperature. No precautions were taken to prevent the calorimeter taking up heat from its surroundings, and, no doubt, it absorbed considerable in the long time, and yet the maximum fall in temperature amounted to 2.4° C., very large, considering the small weight of the reagents compared with the calorimeter. Thus it appears that sodium and potassium are, under such circumstances, a "freezing mixture," and analogy at least would lead one to believe that other alloys also absorb heat in their formation; but future experiment must decide the point.

In the cool vessel above described a piece of sodium or potassium was placed upon a piece of dry ice; almost instantly the reaction commenced and proceeded vigorously. It is, however, scarcely safe to consider this a case of chemical action between solids, because the reaction is probably as follows: The vapor from the ice attacks the metal, forming the hydrate which unites with other ice, forming a solution, which is then further acted upon by the metal, and in the whole process heat is generated sufficient to raise the temperature of the reagents very considerably. Perhaps in the other freezing mixtures, ice and salt, etc., it is the vapor of the water or ice which initiates the reaction.

In view of these and other considerations, the idea is evident that perhaps many substances have a slight vapor tension at temperatures considerably below their melting points, and are surrounded by a thin atmosphere of their own vapor over their clean surfaces, and it is only necessary to bring two such atmospheres to interpenetration in order to initiate the reaction which will then continue, provided the product (liquid or gas) escapes easily and does not clog the operation. In very many cases substances are found to give off a vapor below their melting point, and it is natural to suppose that there is a film of that vapor over the surface of the body, as there is a layer of saturated air over water. The mechanical theory of the composition of matter lends plausibility to the above suggestion. If these considerations are correct they foretell the regelation of substances like camphor and ice, without any pressure whatever. That loose pieces of camphor will become welded together by simple contact is well known. The operation appears to me thus: In an irregular mass of camphor in an atmos-

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phere of camphor vapor, there is a constant interchange of state for the molecules at the surfaces of the solid, molecules previously solid are getting too far off and becoming gas, and molecules previously gas are beating upon the solid and staying there; thus the state of equilibrum is when, as a whole, there are as many molecules which fly off and become gas as fly on and become solid. On a projecting point of the solid the chances are in favor of more flying off than on; in a reentrant angle the reverse is true. Theoretically, then, the piece ought ultimately to become a sphere, not only by the rounding down of the corners, but by the building up of the flat or reentrant sides. That the corners do round off all know. If this is all true we only need to bring the two pieces together and consider them as one, and the crack between them as a reentrant angle, and the union is brought about as above indicated. If in the above the word liquid be substituted for vapor or gas, the explanation will apply to the regelation of ice in water at 0° C.

We may go even further and predict a uniting without actual contact, and this prediction has been experimentally demonstrated in the case of ice and water. A large rough block of ice (about 15 pounds) was sawed nearly in two, the slit washed out and all the fine pieces removed. In this way it was possible to hold two plane surfaces of ice parallel and near each other (1 to 2^{mm}) without danger of actual contact. Into the outer edge of the saw-cut a cotton wick was pressed, thus isolating the space between the faces from the outside and preventing any currents from circulating through the crack. The whole block was then placed in water at zero and inclosed in non-conducting cases and left for twenty-five to thirty hours. This experiment was tried three times and each time a freezing across the space had taken place. The whole space was not filled, but in numerous places, notably along just inside the wicking and up from the bottom of the cut. No doubt the regelation would have gone further if the experiment could have been continued longer. The melting of the whole block puts an end to each experiment. As these experiments were performed in summer there is scarcely a possibility that the ice was colder than 0° C.

Inasmuch as there appears to be an increasing inclination to regard solutions and alloys as chemical compounds, it seems justifiable to speak of the action according to the alloy law as chemical. On the other hand, there are some cases which at first appear as chemical action between solids which upon closer investigation can be explained on a simpler assumption.

For example, Mr. W. Spring,[1] in a recent paper on this subject, cites three particular cases as being chemical action between solids, the union of copper and sulphur, the reaction between copper and mercuric chloride, and between potassium nitrate and sodium acetate.

The formation of the sulphide of copper and other sulphides was accomplished by Mr. Spring by compression of the elements. But it is

[1] W. Spring, Zeitschr. für phys. Chemie, vol. 2, 1888, p. 536.

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not even necessary that the sulphur and copper be in contact. I have made the sulphide at ordinary temperatures with the two an inch apart and a wad of cotton in the tube between them. It is simply the *vapor* of sulphur which attacks the copper. That sulphur gives off a perceptible vapor at ordinary temperatures, especially in vacuo, is a fact any one can easily demonstrate. The case of the copper and mercuric chloride is precisely the same. The *vapor* of the chloride will go through a whole tube past cotton wads and attack the copper, or color potassic iodide. Hence we can scarcely assert that these reactions are between *solid* bodies. The reaction between potassium nitrate and sodium acetate is equally unconvincing. Mr. Spring expected an interchange of bases and acids and left the mixture of the dry fine powders four months in a desiccator to give time for the exchange. On removing them from the desiccator a deliquescence was noticeable and he therefore concludes that the interchange had taken place, since the original salts do not easily deliquesce; but the product of the reaction (potassium acetate) does. It appears to me thus: The moment the powders were brought to the air, the water vapor enters the operation and we have potassium nitrate, water vapor, and sodium acetate, and the result of their mutual interaction is a solution of potassium acetate and sodium nitrate. In fact, if the dry powdered salts are stirred together, in a very few moments deliquescence begins, showing that whatever the reaction it goes on at once, and is a matter of moments and not of months. Thus even this experiment in its present form does not convince us that a chemical exchange took place *before* the water vapor entered the reaction.

The question of chemical action between solids is by no means new, but is being constantly extended. I may say I believe chemical action may take place wherever the product or products are liquid or gaseous even though the reagents are solid, with perhaps the added condition that one or both the reagents be soluble in the liquid produced. If this be true my new method of forming alloys is but a special case of the above general principle.[1]

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[1] Experiments endeavoring to produce carbon disulphide from the elements at ordinary temperatures, are in hand and give promise of positive results. Also, experiments on the interaction of potassium nitrate and sodium acetate have been started; it will, however, be some time before further results can be given.

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THE FLOW OF SOLIDS: A NOTE.

By William Hallock.

The American Journal of Science, vol. 34, 1887, p. 277, contained an abstract of my paper under the above title, which appears in full in Bulletin 55 of the U. S. Geological Survey. The results obtained were so different from those of Mr. Spring that I was led to a criticism of his work and seem to have been misunderstood.[1]

The justice of Mr. Spring's[2] protest against a part of my original paper I am glad to admit, as far as it concerns an ill-advised use of terms, and a consequent misrepresentation of his views, of course entirely unintentional. Not realizing that many were not so familiar with Mr. Spring's works as myself, I neglected in the brief paper to give his views, and thus my deductions from his results seemed to represent his own conclusions.

The object of my original investigation[3] was a solution of the question whether pressure alone is capable of producing true liquefaction; many have certainly believed so, or even do believe so, and a few, at least, including myself, saw in Mr. Spring's earlier results evidence of such a possibility. I believe that to produce such phenomena, as some recrystallizations, and diffusion, an increase in the freedom of motion of the molecule, an increased diffusibility, *i. e.*, the beginning of a liquefaction, is indispensable. Hence I looked upon his results as pointing to a liquefaction by pressure. My own experiments with the same substances and pressures showed the impossibility of liquefying them by pressure and even brought out an enormous increase in the rigidity of bees-wax and paraffin[4] under such pressures. In concluding I wished only to call attention to the difference between Mr. Spring's *results* and my own, but unfortunately a loose and abbreviated quotation caused the misunderstanding, which I wish to explain.

Since obtaining my own results there seems to me little doubt that many, at least, of Mr. Spring's effects are caused rather by a *motion*

[1] The following appeared in Am. Jour. Sci., vol. 36, 1888, p. 60.

[2] W. Spring, Am. Jour. Sci., vol. 35, 1888, p. 78, also Bull. de l'Acad. R. Belg., vol. 14, 1887, p. 585.

[3] W. Hallock, Am. Jour. Sci., vol. 34, 1887, p. 277.

[4] Compare also Ordnance Department Tests of Metals, etc., 1884, Government Printing Office, pp. 252-254, 285-287.

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under pressure, a kneading, as it were, and by the regrinding. The holders in which his compressions were made were not tight and the most perfect welding[1] always took place at the surface of the block, or the corners, or where the material was forced into the cracks, often even while the center, under eqnal pressure, remained almost unaffected. My holders were tight, allowing no leaking or motion, and the substances showed scarcely a trace of a welding under pressure. I must therefore reiterate that which I wished originally to impress, namely, that the majority of Mr. Spring's results are not produced by simple cubic static pressure.

In the cases of chemical action and the formation of alloys, I believe that the *motion under pressure* will be found to be the all important factor, perhaps just as stirring assists diffusion to completely mix two liquids. Even if blocks of barium sulphate and of sodium carbonate[2] were brought into actual chemical contact, I think no one would expect that simple diffusion would complete the interchange of bases and acids in finite time so long as both substances remained solid; nor that a piece of copper and of tin soldered together would diffuse and form a homogeneous bronze; nor would they expect that simple cubic static pressure would promote these reactions; if pressure will assist them to completion, it will increase the diffusibility of solids, increase the freedom of motion of their molecules; that is, it will make them more like liquids—will begin to liquefy them.

I wish to refer here to a new law I recently proposed[3] concerning the formation of alloys, where the fact is brought out that the melting point and liquidity of the product are quite as important as those of the constituents in determining the possibility of a reaction. Mr. Spring[4] has produced Wood's alloy by compressing the constituents together, and quotes Mr. Romna[5] as having failed to obtain fine platinum wire by electro silver-plating a platinum wire, drawing it down and dissolving off the silver in nitric acid, because the silver and platinum alloyed under the pressure of the draw plate. Messrs. W. & L. E. Gurley, of Troy, N. Y., have for several years made fine platinum wires by the well-known Wollaston[6] method of *casting* silver around the platinum and treating as above. In the note referred to[4] I have described the production of Wood's alloy *without pressure at* 100° C. of a tin-lead alloy at 190° C. of the sodium-potassium alloy at ordinary temperatures, etc. Hence it appears to me that pressure alone is the least important factor in the production of the effects obtained in Mr. Spring's investigation.

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[1] W. Spring, Bull. d. l'Acad. R. Belg., vol. 49, 1880, p. 352. Phosphore amorphe et seq.

[2] W. Spring, Bull. Soc. Chem., vol. 44, 1885, p. 166.

[3] W. Hallock, Science, Mar. 2, 1888, vol. 11, p. 100; also Ostwald Zeitschr. f. Phys. Chem., vol. 2, 1888.

[4] W. Spring, Ber. der deutsch. Chem. Gesell., vol. 15, 1882, p. 595.

[5] Ibid.

[6] Ganot's Physics, Atkinson, New York, 1883, p. 76.

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MISCELLANEOUS ANALYSES.

1. TYROLITE.[1]

From the Mammoth Mine, Tintic district, Utah. New material, very pure, collected and analyzed by W. F. Hillebrand.

CuO	45.08
FeO	.08
CaO	6.78
MgO	.04
H_2O	17.21
As_2O_5	28.52
SO_3	2.23
Insoluble	.16
	100.10

2. GADOLINITE.

From Llano County, Texas. Analyzed by L. G. Eakins.[2]

SiO_2	23.79
ThO_2	.58
Fe_2O_3	.96
Ce_2O_3	2.62
$(DiLa)_2O_3$	5.22
$(YEr)_2O_3$	41.55
FeO	12.42
GlO	11.33
MnO	trace
CaO	.74
MgO	trace
Alkalies	trace
H_2O	1.03
P_2O_5	.05
	100.29

In the rare earths from this mineral the absorption spectrum of didymium was strong, and that of erbium was weak. The molecular weight of the oxide $(YEr)_2O_3$ was 260.

[1] Compare analyses in Bulletin 55, p. 41.

[2] Compare Hidden & Mackintosh, Am. Jour. Sci., Dec., 1889.

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3. WARWICKITE.

From the well-known locality at Edenville, Orange County, New York. Analyzed by J. E. Whitfield. The material could not be completely freed from an admixture of spinel.

SiO_2	1.16
TiO_2	18.68
FeO	14.23
Al_2O_3	9.44
B_2O_3	18.96
CaO	.38
MgO	34.41
H_2O	2.80
	100.06

From this composition no simple formula can be deduced; but if we reject obvious impurities, and throw out the alumina in the form of spinel, the residue agrees approximately with the ratios

$$TiO_2 . B_2O_3 . 4R''O.$$

This expression is not quite satisfactory, and may need revision.

4. MINERALS AND ROCKS FROM MARYLAND.

Collected by Dr. G. H. Williams.

Chrome tourmaline and fuchsite.—Found in chrome pits a mile west of Etchison post-office, a little east of Great Seneca Creek, in Montgomery County. The tourmaline occurs in dark-green needles, with chromite, and the mica is associated with it. Analyses by T. M. Chatard.

	Tourmaline.	Fuchsite.
H_2O	3.74	6.77
SiO_2	36.57	42.21
B_2O_3	8.90	.....
F	.06	.....
P_2O_5	.04	.....
TiO_2	.09	.....
Al_2O_3	32.58	34.55
Cr_2O_3	4.32	2.03
Fe_2O_3, FeO	.79	1.03
NiO	.05	.....
MnO	trace	trace
CaO	.75	.47
MgO	9.47	3.13
Li_2O	trace	.....
Na_2O	2.22	.82
K_2O	.13	9.16
	99.71	100.17

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These minerals are more fully discussed by G. H. Williams and A. C. Gill in Circular No. 75 of the Johns Hopkins University. In the same paper is described epidote from the Woodstock granite, of which the following analysis has been made by Dr. W. F. Hillebrand, on only 0.4473 gramme of material:

SiO_2	37.63
$Fe_2O_3(+FeO)$	15.29
Al_2O_3	18.40
TiO_2	3.78
MnO	.31
CaO	22.93
MgO	.31
P_2O_5	.44
Ignition	2.23
	101.32

Rocks from Baltimore County.—Analyses by J. E. Whitfield. A, pyroxenite, Johnny Cake Road. B, pyroxenite, Johnny Cake Road, first stage of alteration. C, pyroxenite, Johnny Cake Road, second stage of alteration. D, smaragdite, Dogwood Road.

	A.	B.	C.	D.
SiO_2	50.80	50.10	51.94	53.22
SO_3	trace	trace	.19	trace
Cl	.24	.26	.16	.26
P_2O_5	trace	none	none	.....
Al_2O_3	3.40	2.00	2.53	3.14
Cr_2O_3	.32	.36	.60	.23
Fe_2O_3	1.39	2.38	2.88	trace
FeO	8.11	8.68	9.38	7.95
MnO	.17	.29	trace	.11
CaO	12.31	5.06	3.60	14.44
MgO	22.77	26.85	25.97	20.09
Alkalies	traces	none	none	traces
H_2O	.52	4.16	2.82	.98
	100.03	100.14	100.07	100.42

Titanium was absent from all four.

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Another pyroxenite (E), and a diallage-bronzite rock (F), from the same region, were analyzed by T. M. Chatard.

	E.	F.
SiO_2	43.87	58.98
TiO_2	.12	.15
P_2O_5	trace	trace
Al_2O_3	1.64	1.82
Cr_2O_3	.44	.53
Fe_2O_3	8.94	1.41
FeO	2.60	3.90
MnO	.19	.21
NiO	trace	trace
CaO	6.29	15.47
MgO	27.82	22.59
Alkalies ($AsNa_2O$)	.50	undet.
H_2O	8.72	.92
	100.63	100.48

5. SERPENTINE AND ITS ASSOCIATES.

From Moriah, New York.—Derived from pyroxene. Four analyses by Charles Catlett, as follows: A, serpentine from the ophiolite of Reed's Quarry. B, "dolomite" from the same rock. C, pyroxene from an abandoned quarry. D, serpentine derived from the same pyroxene.

	A.	B.	C.	D.
SiO_2	39.96	2.60	55.36	42.17
Al_2O_3	1.07	.09	.22	.30
Fe_2O_3	3.53	none	.18	1.57
FeO	3.85	.80	.57	.64
MgO	37.61	2.49	19.53	41.33
CaO	none	52.38	24.48	none
CO_2	none	41.77	.....	none
MnO	trace	.04	trace	trace
H_2O	13.65	.....	.....	13.72
	99.67	100.17	100.34	99.73

Chromium and nickel sought for, but absent.

Serpentine from the aqueduct shaft, New York City.—Analyzed by Mr. Catlett:

SiO_2	39.92
Al_2O_3	.08
Fe_2O_3	.50
FeO	none
MgO	42.52
CO_2	1.64
CaO	.90
H_2O at 105°	1.36
Ignition	13.26
	100.18

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From Montville, New Jersey.—A, very pale serpentine, somewhat resembling deweylite in appearance. B, mineral, resembling actinolite. C, brown mica, first zone above pyroxene. D, yellowish mica, second zone above the pyroxene. E, white mica, associated with pyroxene. Analyses A and B, by L. G. Eakins; C, D, and E, by Charles Catlett. In D and E the ferrous oxide was not separately estimated for want of sufficient material.

	A.	B.	C.	D.	E.
H_2O	14.73	1.17	5.07	10.88	10.20
CO_2	.....	.....	.30	1.80	.....
SiO_2	40.64	43.31	39.38	32.52	39.14
Al_2O_3	2.74	17.41	15.92	18.14	15.70
Fe_2O_3	.81	.71	.71	2.30	1.68
FeO	.28	.59	.80		
MnO	trace	.14	trace	trace	trace
CaO	trace	12.84	.28	1.44	5.24
MgO	40.93	19.39	26.85	29.26	25.44
Na_2O	.....	2.23	.62	1.38	.64
K_2O	.....	1.36	9.84	2.78	2.06
F	.....	.....	.62	.....	.....
	100.13	99.15	100.39	100.50	100.10
Less O	.....	.....	.26		
			100.13		

Associates of serpentine from Easton, Pennsylvania.—A, vermiculite, analyzed by C. Catlett; B, tremolite; C, so-called "nephrite." Analyses B and C by L. G. Eakins.

	A.	B.	C.
SiO_2	42.21	58.27	60.29
Al_2O_3	9.37	.33	20.83
Fe_2O_3	.68	trace	trace
FeO	none	.....	.....
MnO	none	.08	.....
CaO	none	11.90	.16
MgO	34.80	25.93	6.44
Na_2O	1.25	1.25	1.97
K_2O	1.34	.42	8.41
H_2O	10.70	1.22	1.13
	100.35	99.40	99.23

All of the foregoing minerals were collected by Mr. G. P. Merrill.

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6. GEYSERITES FROM ROTORUA, NEW ZEALAND.

Received from the museum at Auckland. Analyzed by J. E. Whitfield for comparison with the geyserites of the Yellowstone Park, which they closely resemble. Three samples:

	1.	2.	3.
SiO_2	92.47	90.28	74.63
Al_2O_3	2.54	3.00	15.59
CaO	.79	.44	1.00
MgO	.15	trace	trace
Na_2O	.....	.....	.30
K_2O	.....	.....	1.02
Ignition	3.99	6.24	7.43
	99.94	99.96	99.97

7. MISCELLANEOUS ROCKS.

Sandstone from Buena Vista, Ohio.—A yellowish building stone. Partial analysis by F. W. Clarke.

Moisture	2.51
SiO_2	88.27
$Al_2O_3+Fe_2O_3$	9.09
MgO	trace
	99.87
Insoluble in HCl	96.47
Soluble Fe_2O_3	.77

Sandstone from near Portsmouth, Ohio.—The "Peebles-Henley" or "Otway" building stone. Three samples, analyzed by T. M. Chatard. In B and C the iron was mainly ferrous, though weighed as Fe_2O_3.

	A.	B.	C.
Ignition	1.08	1.46	1.95
Insoluble in HCl	98.31	97.20	95.83
Soluble	.61	1.40	2.42
	100.00	100.06	100.20
Soluble Fe_2O_3	.61	1.04	1.65
Soluble CaO	trace	.36	.77
Soluble MgO	trace	little	trace

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Limestone from Silverdale, Kansas.—Analyzed by Charles Catlett.

SiO_2	5.27
Al_2O_3	1.07
Fe_2O_3	.71
FeO	.32
CaO	50.36
MgO	.56
Na_2O	.20
K_2O	.10
CO_2	40.34
SO_3	.07
P_2O_5	.06
H_2O	.78
	99.84

Metamorphic rock from Marion, Kentucky.—Analyzed by L. G. Eakins.

SiO_2	34.50
Al_2O_3	14.37
Fe_2O_3	2.85
FeO	4.46
CaO	11.43
MgO	21.81
K_2O	1.50
Na_2O	.51
H_2O	7.14
P_2O_5	.77
SO_3	.60
CO_2	.21
	100.15

From Pigeon Point, Michigan.—Analyses by L. G. Eakins. A, red porphyry from Brick Island, Lake Superior, near Pigeon Point. B, green mottlings from Pigeon Point. Van Hise's rock, No. 11908.

	A.	B.
SiO_2	73.70	83.27
TiO_2	.12	trace
Al_2O_3	12.87	7.81
Fe_2O_3	3.76	1.99
FeO	.31	1.81
MnO	.07	.....
CaO	.14	.20
MgO	.11	1.59
K_2O	4.56	1.11
Na_2O	3.63	.19
H_2O	.57	2.32
P_2O_5	trace	trace
	99.84	100.29

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Diabase, Penokee-Gogebic Range, Michigan.—Analyses by T. M. Chatard. A, from near SE. corner of Sec. 13, T. 47 N., R. 46 W. B, altered diabase, same locality. C, altered diabase, Aurora Mine, NE. ¼ of SW. ¼ Sec., T. 47 N., R. 47 W. D, feldspar separated from A.

	A.	B.	C.	D.
H_2O, at 105°	.15	3.12	.29	1.19
H_2O, at red heat	2.34	8.25	13.54	
CO_2	.38	1.89	.38	1.89
P_2O_5	.13	.16	.14	.....
SiO_2	47.90	46.85	41.60	51.18
TiO_2	.82	1.12	3.79	.....
Al_2O_3	15.60	22.62	37.20	27.00
Fe_2O_3	3.69	5.12	3.21	3.19
Cr_2O_3	trace	.....	.....	.....
FeO	8.41	1.58	.30	undet.
NiO	.10	.08	.....	.....
MnO	.17	2.54	.08	.17
BaO	.05	.10	trace	.....
CaO	9.99	1.25	.23	11.70
MgO	8.11	2.01	.02	1.92
K_2O	.23	2.66	.....	.41
Na_2O	2.05	.80	.07	3.48
	100.12	100.15	100.85	100.24

Penokee-Gogebic rocks from Wisconsin.—A, B, C, three slates, analyzed by L. G. Eakins. A, from Sec. 6, T. 45 N., R. 2 E. B, from Sec. 1, T. 45 N., R. 1 E. C, from Sec. 4, T. 44 N., R. 2 W.

	A.	B.	C.
SiO_2	53.44	59.73	52.58
Al_2O_3	19.62	22.78	20.76
Fe_2O_3	11.38	.11	12.17
FeO	5.35	5.98	4.08
MnO	trace	.09	.21
CaO	.42	.53	.30
MgO	1.58	2.94	1.33
K_2O	1.73	3.48	4.87
Na_2O	2.61	1.41	.37
Li_2O	trace	.....	trace
H_2O	4.07	3.28	3.43
P_2O_5	trace	.....	.....
	100.20	100.33	100.10

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D, E, F, three feldspars, analyzed by T. M. Chatard. D, from gabbro, center of Sec. 14, T. 44 N., R. 4 W. E, F, from olivine diabase, NE. ¼ Sec. 13, T. 45 N., R. 1 W.

	D.	E.	F.
H_2O, at 105°	.03	.95	.13
H_2O, at red heat	.54		.64
SiO_2	51.99	61.65	56.15
Al_2O_3	29.32	19.91	26.05
Fe_2O_3	1.23	2.23	1.98
FeO	undet.	undet.	undet.
MnO	trace	trace	.13
CaO	12.60	4.12	8.70
MgO	.63	.61	.54
K_2O	.28	5.72	1.56
Na_2O	2.91	4.74	4.79
	99.53	99.98	100.67

Eruptive rock from four miles southwest of Hot Springs, Arkansas.—Analyzed by L. G. Eakins.

SiO_2	36.40
TiO_2	.42
Al_2O_3	12.94
Fe_2O_3	8.27
FeO	4.59
CaO	14.46
MgO	11.44
K_2O	3.01
Na_2O	.97
H_2O	2.36
CO_2	3.94
P_2O_5	1.04
	99.84

Recent lava from two miles south of Mount Trumbull, Arizona.—Analyzed by L. G. Eakins.

SiO_2	45.30
TiO_2	2.66
Al_2O_3	14.95
Fe_2O_3	1.98
FeO	9.32
MnO	trace
CaO	8.87
MgO	8.29
K_2O	1.27
Na_2O	4.27
H_2O	.85
P_2O_5	2.23
	99.99

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Eruptive rock from Castle Mountain, Montana.—Analyzed by L. G. Eakins.

SiO_2	44.66
TiO_2	1.02
Al_2O_3	12.12
Fe_2O_3	5.81
FeO	3.20
MnO	.21
CaO	8.14
MgO	8.77
K_2O	2.75
Na_2O	4.47
H_2O	4.33
CO_2	2.19
P_2O_5	2.02
	99.69

Rocks from Northern California.—Collected by J. S. Diller. A, B, porphyritic rocks from Shasta County; analyzed by J. E. Whitfield. A, east fork of Clear Creek, nine miles from French Gulch. B, Smith's Gulch, six miles up Clear Creek from French Gulch.

	A.	B.
SiO_2	66.30	64.24
TiO_2	trace	.76
SO_3	.28	.22
Cl	none	.25
P_2O_5	.15	.08
Al_2O_3	17.55	18.67
Fe_2O_3	2.19	1.40
FeO	.55	1.96
MnO	trace	trace
CaO	3.12	4.11
MgO	.97	1.48
Na_2O	5.15	4.14
K_2O	2.45	1.71
H_2O	1.25	1.18
	99.96	100.20

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C, D, two rocks from three-fourths of a mile below John Allen's, Dry Creek, Shasta County. E, from John Allen's. F, from two and one-half miles above John Allen's. Analyses by Whitfield.

	C.	D.	E.	F.
SiO_2	59.10	61.60	54.55	60.74
TiO_2	.70	trace	trace	.86
SO_3	trace	.27	.10	.40
Cl	trace	trace	.12	trace
P_2O_5	trace	.08	.10	trace
Al_2O_3	14.02	12.15	10.64	10.25
Fe_2O_3	3.16	2.09	1.59	4.81
FeO	1.42	3.30	1.16	6.21
MnO	trace	trace	1.53	trace
CaO	9.35	6.92	14.30	4.97
MgO	1.72	2.33	1.29	3.69
Na_2O	2.21	2.16	2.60	1.83
K_2O	1.49	1.41	1.68	.52
CO_2	4.65	5.05	9.05	2.29
H_2O	2.63	3.10	1.60	4.36
	100.45	100.46	100.31	100.43

G, eruptive rock, Great Bend of Pit River. H, black obsidian, Medicine Lake, Modoc County; analyses by L. G. Eakins.

	G.	H.
SiO_2	44.77	73.51
TiO_2	.53	.....
P_2O_5	.72	.04
Al_2O_3	17.82	14.42
Fe_2O_3	5.05	.46
FeO	6.95	1.49
MnO	trace	trace
CaO	10.36	1.26
MgO	8.22	.33
Na_2O	2.13	4.03
K_2O	.92	4.29
H_2O	2.64	.40
	100.11	100.23

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8. SOILS AND CLAYS.

A, kaolin from Talladega, Alabama. B, clay from Richfield Springs, New York; partial analysis. C, D, two clays from Northumberland County, Pennsylvania; analyses by Charles Catlett.

	A.	B.	C.	D.
H_2O, at 120°	5.02	16.18	6.28	6.87
H_2O, at red heat	13.48			
SiO_2	43.21	49.65	65.97	59.16
Al_2O_3	37.27	23.82	20.37	18.68
Fe_2O_3	trace		2.75	10.32
CaO	.11	6.48	.64	.52
MgO	.10	trace	.52	.67
K_2O	.28	undet.	3.32	3.35
Na_2O	.40	undet.	.05	.11
	99.87	96.13	99.90	99.68

E, F, G, H, adobe soils. E, from Santa Fé, New Mexico. F, Fort Wingate, New Mexico. G, Humboldt City, Nevada. H, Salt Lake City, Utah. Analyses by L. G. Eakins.

	E.	F.	G.	H.
SiO_2	66.69	26.67	44.64	19.24
Al_2O_3	14.16	.91	13.19	3.26
Fe_2O_3	4.38	.64	5.12	1.09
MnO	.09	trace	.13	trace
CaO	2.49	36.40	13.91	38.94
MgO	1.28	.51	2.96	2.75
K_2O	1.21	trace	1.71	trace
Na_2O	.67	trace	.59	trace
CO_2	.77	25.84	8.55	29.57
P_2O_5	.29	.75	.94	.23
SO_3	.41	.82	.64	.53
Cl	.34	.07	.14	.11
H_2O	4.94	2.26	3.89	1.67
Organic matter	2.00	5.10	3.43	2.96
	99.72	99.97	99.84	100.35

9. ORES OF IRON AND MANGANESE.

Manganese ore, Powell's Fort, east end of Massanutten Mountain. Warren County, Virginia. Analysis by Charles Catlett.

SiO_2	9.20
Fe	3.07
Mn	48.59
P	.349
S	.12

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Iron and manganese ores, Montebello, Nelson County, Virginia. Analyses by Catlett.

	Iron.	Manganese.
SiO_2	16.47	1.68
Fe	51.10	2.60
Mn	.65	46.99
P	.152	.464
S	.11	.21

Ores from Rockbridge County, Virginia; analyzed by T. M. Chatard. A, top of hill above Hart's Bottom, one and three-fourths miles southwest of Green Forest Station, near Lockland Station. B, Moorman Quarry, Green Forest. C, new opening, No. 2, Buena Vista. D, opening, No. 3, 40-foot vein, Buena Vista. E, Chalk Mine Branch. F, Old Colonial opening, Buena Vista.

	A.	B.	C.	D.	E.	F.
H_2O, 105°	.72	.15	.39	.60	.45	.48
Insoluble	20.40	13.47	22.55	16.60	8.05	5.43
Soluble Al_2O_3	1.67	.....	.37	1.81	.46	.....
TiO_2	.16	.....	.....	.....	.....	.....
Fe_2O_3	3.11	76.19	66.58	71.16	78.24	82.15
NiO	.....	.....	.27	.....	.....	.....
MnO	53.91	.45	.22	.11	.66	.19
BaO	.23	.....	.....	.....	.....	.....
SO_3	.32	.14	.09	.37	trace	.08
P_2O_5	.50	.26	.42	.50	.88	1.04
Fe	2.18	53.33	46.60	49.81	54.76	57.50
Mn	41.59	.....	.....	.....	.....	.....
P	.22	.11	.18	.22	.38	.45
S	.12	.06	.03	.14	.....	.02

Two manganese ores. Cripple Creek, eight miles from Wytheville, Virginia. Analyses by C. Catlett.

	1.	2.
SiO_2	47.30	27.86
Fe	2.72	3.61
Mn	24.85	32.55
P	.05	.097
S	trace	.030

Iron ore from Shanghai, West Virginia. Analyzed by C. Catlett.

SiO_2	45.24
Fe	26.02
Mn	.43

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Two iron ores from Kentucky; analyzed by J. E. Whitfield. A, Cloverport Road, two miles north of Fordsville, Ohio County. B, north slope of Pine Mountain, three miles east of Pineville, Bell County.

	A.	B.
SiO_2	35.67	17.28
TiO_2	trace	trace
Cl	trace	.....
SO_3	.42	.40
P_2O_5	1.42	trace
Al_2O_3	6.15	.35
Fe_2O_3	42.31	68.24
FeO	.35	trace
MnO	.84	.95
CaO	1.90	.83
MgO	1.67	.92
Ignition	9.69	11.60
	99.82	100.57
Fe	29.86	47.77
P	.71	.....
S	.16	.15

Iron ore. Douglass Mine, Clinton Horizon, one mile west of Big Creek Gap, Campbell County, Tennessee. Analyzed by W. F. Hillebrand.

SiO_2	10.51
Fe	54.29
Mn	.20
P	.355
S	.043

Two iron ores; analyzed by C. Catlett. A, from Edgefield County, South Carolina. B, north part of Howard County, Arkansas.

	A.	B.
SiO_2	9.40	28.10
Fe	52.40	29.57
Mn	trace	2.19
P	.664	.483
S	.08	.04

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10. COAL AND COKE.

Three coals. Raccoon Fork of Cabin Creek, Kanawha County, West Virginia. Analyzed by E. L. Howard.

	1.	2.	3.
Moisture	1.93	2.15	1.67
Volatile matter	37.09	23.95	41.36
Fixed carbon	57.90	61.85	53.22
Ash	3.08	12.05	3.75
	100.00	100.00	100.00
Sulphur	.62	.46	.80
Ash	dirty white	light gray	reddish

Coal and coke. Davis Mine No. 1, near North Fork of Blackwater, Tucker County, West Virginia. Analyzed by Charles Catlett.

	Coal.	Coke.
Moisture	.80	.18
Volatile matter	26.84	1.49
Fixed carbon	67.18	90.60
Ash	5.18	7.73
	100.00	100.00
Sulphur	1.68	.771
Ash	very light red	light red

Five coals. Campbell County, Tennessee; A, B, C analyzed by W. F. Hillebrand; D, E by Charles Catlett. A, Douglass Bank, Middle Fork of Big Creek, one and one-half miles from Gap, lower coal-measures. B, Walnut Mountain, head of Hickory Creek, Clear Fork of Cumberland River, 2,850 feet above sea-level, upper coal-measures. C, Middle Fork of Big Creek, lower coal-measures. D, East Fork of Big Creek. E, Middle Fork of Big Creek, three miles from Big Creek Gap.

	A.	B.	C.	D.	E.
Moisture	1.49	2.95	1.11	1.70	7.60
Volatile matter	39.00	38.51	35.59	39.41	34.89
Fixed carbon	53.30	55.42	23.99	55.36	53.14
Ash	6.21	3.12	39.31	3.53	4.37
	100.00	100.00	100.00	100.00	100.00
S	1.53	.87	2.78	1.07	.64
P	.041	.....	.....	.....	.....

A rough test on C showed that one ton of coal should yield 40,000 cubic feet of gas.

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Also two cokes, analyzed by C. Catlett. F, Walnut Mountain, Hickory Creek. G, from Sharp coal, Left Fork of Big Creek.

	F.	G.
Moisture	.20	.50
Volatile matter	2.01	1.95
Fixed carbon	85.56	91.71
Ash	12.23	5.84
	100.00	100.00
S	.886	.705
P	.040	undet.

Thirty-two coals from Gunnison County, Colorado. Collected by G. H. Eldridge, and analyzed by L. G. Eakins.

From Anthracite Creek Mines.

Moisture	3.95
Volatile matter	4.65
Fixed carbon	82.34
Ash	9.06
	100.00
S	.63
P. in ash	.07
Specific gravity	1.644—24.4°

Ash, light red; no coke.

From Green Mountain, Denver Beds.

Moisture	8.91
Volatile matter	46.16
Fixed carbon	44.46
Ash	.47
	100.00
S	.47
Specific gravity	1.381—22.5°

Ash, light red; coke moderately coherent.

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From Ohio Creek Mines, Nos. 1 to 11.

	1.	2.	3.	4.	5.
Moisture	7.39	8.46	8.26	1.61	1.34
Volatile matter	39.43	39.01	39.96	13.05	30.25
Fixed carbon	47.83	46.68	46.36	80.29	62.38
Ash	5.35	5.85	5.42	5.05	6.03
	100.00	100.00	100.00	100.00	100.00
S	1.47	.76	.68	.59	.44
P. in ash			.06		.07
Specific gravity	1.328, 23°	1.334, 21.6°	1.331, 25°	1.407, 23°	1.325, 23°
Ash	reddish gray	light red	light red	red	red
Coke	fairly coherent	cokes slightly	cokes slightly	none	firm, solid

	6.	7.	8.	9.	10.	11.
Moisture	6.28	6.37	6.39	1.07	1.23	.81
Volatile matter	40.92	38.06	39.26	26.22	26.65	9.96
Fixed carbon	46.35	49.75	48.41	68.36	68.27	82.33
Ash	6.45	5.82	5.94	4.35	3.85	6.90
	100.00	100.00	100.00	100.00	100.00	100.00
S	.47	.46	.46	.60	.61	1.06
P. in ash			.03	.05		
Specific gravity	1.324, 21°	1.345, 21.6°	1.337, 23°	1.319, 22°	1.317, 22°	1.426, 23.8°
Ash	reddish yellow	reddish yellow	red	red	red	pinkish gray
Coke	fair	slightly coherent	fair	fair	fair	none

From Slate Creek Mines, Nos. 12 to 21.

	12.	13.	14.	15.	16.
Moisture	1.29	1.36	1.86	1.35	1.30
Volatile matter	7.92	7.53	6.68	6.59	7.55
Fixed carbon	85.71	85.49	86.25	72.34	80.44
Ash	5.08	5.62	5.21	19.72	10.71
	100.00	100.00	100.00	100.00	100.00
S	.67	.54	.69	.66	.58
P. in ash		.05	.03		.32
Specific gravity	1.428, 23.4°	1.440, 21.8°	1.465, 26.4°	1.481, 22.2°	1.502, 22.8°
Ash	red	red	red	gray	light red
Coke	none	none	none	none	none

	17.	18.	19.	20.	21.
Moisture	1.58	1.22	1.27	.92	.81
Volatile matter	6.70	8.46	7.99	14.19	13.40
Fixed carbon	87.46	84.20	87.24	81.29	81.26
Ash	4.26	6.12	3.50	3.60	4.53
	100.00	100.00	100.00	100.00	100.00
S	.58	.76	.62	.52	.51
P. in ash				none	
Specific gravity	1.455, 22.8°	1.409, 22°	1.409, 23.3°	1.359, 20.4°	1.371, 20.8°
Ash	red	red	red	light red	red
Coke	none	none	none	cokes slightly	cokes slightly

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From Crested Butte Mines, Nos. 22 to 30.

	22.	23.	24.	25.
Moisture	1.36	1.47	1.94	2.36
Volatile matter	37.12	38.09	41.07	40.82
Fixed carbon	57.73	56.68	51.48	50.49
Ash	3.79	3.76	5.51	6.33
	100.00	100.00	100.00	100.00
S	.49	.47	.63	1.04
P. in ash	.....	.07	trace	.....
Specific gravity	1.288, 22.6°	1.276, 21°	1.311, 21.1°	1.332, 22°
Ash	light red	light red	red	red
Coke	good	good	good	good

	26.	27.	28.	29.	30.
Moisture	1.88	2.09	1.76	3.95	4.83
Volatile matter	39.51	41.74	42.00	37.17	37.86
Fixed carbon	54.42	52.07	51.97	52.34	51.65
Ash	4.19	4.10	4.27	6.54	5.66
	100.00	100.00	100.00	100.00	100.00
S	.63	.65	.75	.42	.68
P. in ash	.....	trace	.....	.....	.....
Specific gravity	1.288, 24.8°	1.289, 26.6°	1.286, 20°	1.328, 22.4°	1.349, 21.2°
Ash	red	red	light red	red	red
Coke	good, solid	good	good	hard, compact	fair

11. ANALYSES OF WATERS.

Analyzed by T. M. Chatard. A, from the Murray Well, one mile north of Frankfort, Kentucky. Slight odor of H_2S. Specific gravity, .99984, 22°.

	Found, grammes per liter.	Per cent. of total contents.		Combination.
SiO_2	.0096	.61	CO_2	.0172
Fe	.0014	.08	NH_3	.0015
Ca	.0213	1.35	KCl	.0896
Sr?	.0122	.71	NaCl	.8287
Mg	.0189	1.20	Na_2SO_4	.2770
K	.0207	1.31	$FeH_2C_2O_6$	.0045
Na	.4604	29.35	$CaH_2C_2O_6$	.0862
Li	trace	.....	$SrH_2C_2O_6$?	.0269
SO_4	.1873	11.93	$MgH_2C_2O_6$	.1150
Cl	.5218	33.23	$NaHCO_3$	.1639
CO_2	.2929	18.74	SiO_2	.0096
CO_2, free	.0172	1.09		
NH_3	.0015	.09		
H, in bicarbonates	.0049	.31		
	1.5701	100.00		1.5701

The strontium is doubtful, and may be only a strong trace.

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B, spring water from Mountain City, Tennessee. Statement like the preceding.

	Found.	Per cent. of total.		Combination.
SiO_2	.0219	21.26	SiO_2	.0219
Fe	.0008	.78	$FeH_2C_2O_6$	.0028
Al	trace	.....	$CaH_2C_2O_6$	.0448
Ca	.0116	11.26	$MgH_2C_2O_6$	.0110
Mg	.0018	1.75	$CaSO_4$	.0018
Na	.0046	4.47	Na_2SO_4	.0142
K	.0032	3.11	K_2SO_4	.0042
Cl	.0012	1.16	KCl	.0025
SO_4	.0132	12.81		
CO_2	.0440	42.72		
H, bicarbonates	.0007	.68		
	.1030	100.00		.1030

C, the Grace Spring, seven miles north of Mountain City, Tennessee, on the road to Abingdon, Virginia, near Laurel Bloomery post-office. Specific gravity, 1.00038, 18.5°.

	Found.	Per cent. of total.		Combination.
SiO_2	.0125	1.09	SiO_2	.0125
Fe	trace	.....	KCl	.0023
Ca	.2334	20.31	K_2SO_4	.0075
Mg	.0580	5.05	Na_2SO_4	.0145
K	.0046	.40	$MgSO_4$	.2900
Na	.0047	.41	$CaSO_4$	.6429
Cl	.0011	.09	$CaH_2C_2O_6$	.1794
SO_4	.6997	60.89		
CO_2	.1329	11.57		
H, bicarbonates	.0022	.19		
	1.1491	100.00		1.1491

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D, drinking water, Savannah, Georgia. Stated in grammes per liter.

	Found.		Combination.
Suspended matter (organic)	.0020	Suspended matter	.0025
Suspended matter (inorganic)	.0005	SiO_2	.0624
SiO_2	.0624	Al_2O_3, Fe_2O_3	.0006
Al_2O_3, Fe_2O_3	.0006	NaCl	.0097
Ca	.0279	Na_2SO_4	.0120
Mg	.0085	$CaH_2C_2O_6$	.1129
Na	.0075	$MgH_2C_2O_6$	.0517
Cl	.0061		
SO_4	.0081		
CO_2	.1262		
NH_3, free	trace		
NH_3, albuminoid	none		
H, bicarbonates	.0020		
	.2518		.2518

E, two artesian well waters from St. Augustine, Florida. (*a*) six-inch well.

	Found.	Per cent. of total.		Combination.
Suspended matter	.0037	.24	Suspended matter	.0037
SiO_2	.0224	1.43	SiO_2	.0224
Al_2O_3	.0005	.03	Al_2O_3	.0005
Ca	.1276	8.16	NaCl	.6979
Mg	.0726	4.64	KCl	.0281
Sr	.0081	.52	$MgCl_2$	.1470
Na	.2743	17.54	$SrSO_4$	.0170
K	.0147	.94	$CaSO_4$	.4338
Cl	.5469	34.97	$MgSO_4$	.0127
SO_4	.3253	20.81	$MgH_2C_2O_6$	.2007
CO_2	.1650	10.55	$CaH_2C_2O_6$	none.
H, bicarbonates	.0027	.17		
	1.5638	100.00		1.5638

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(*b*) twelve-inch well.

	Found.	Per cent. of total.		Combination.
Suspended matter	.0016	.05	Suspended matter	.0016
SiO_2	.0280	.88	SiO_2	.0280
Al_2O_3	.0012	.04	Al_2O_3	.0012
Ca	.1755	5.50	NaCl	1.9577
Mg	.1160	3.64	KCl	.0475
Sr	.0089	.28	$MgCl_2$	.3534
Na	.7695	24.12	$SrSO_4$	.0186
K	.0248	.77	$CaSO_4$	.4709
Cl	1.4750	46.22	$MgSO_4$	none.
SO_4	.3421	10.73	$MgH_2C_2O_6$	.1621
CO_3	.2442	7.64	$CaH_2C_2O_6$	.1499
H, bicarbonates	.0041	.13		
	3.1909	100.00		3.1909

F, from well four miles northwest of Clinton, Hinds County, Mississippi. No carbonates present.

	Found.	Per cent. of total.		Combination.
Suspended matter	.0028	.18	Suspended matter	.0028
SiO_2	.0750	4.82	SiO_2	.0750
Al_2O_3	.0077	.49	Al_2O_3	.0077
Fe_2O_3	trace	.....	$Al_2(SO_4)_3$	.0504
Al in sulphate	.0081	.52	$MnSO_4$	.0028
Mn	.0010	.06	$CaSO_4$	.6732
Ca	.1980	12.72	$MgSO_4$	.3695
Mg	.0739	4.78	Na_2SO_4	.2519
Na	.1234	7.92	NaCl	.1063
K	.0088	.56	KCl	.0167
SO_4	.9852	63.30		
Cl	.0724	4.65		
	1.5563	100.00		1.5563

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UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL, DIRECTOR

STRATIGRAPHY

OF THE

BITUMINOUS COAL FIELD

OF

PENNSYLVANIA, OHIO AND WEST VIRGINIA

BY

ISRAEL C. WHITE

WASHINGTON
GOVERNMENT PRINTING OFFICE
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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
APPALACHIAN DIVISION,
Morgantown, W. Va., July 15, 1890.

SIR: I have the honor to transmit herewith the results of my study of the stratigraphy of the bituminous coal rocks in the northern half of the Appalachian field.

As stated in the body of this report, it can not be expected that this first attempt to correlate the different beds of coal, limestone, and sandstone over such a wide area will be free from error, but it represents my best efforts to harmonize the strata of the several regions. No one knows better than I that many of the identifications suggested are largely preliminary, and I not only expect but request the friendly criticism of my brother geologists, knowing that all will be pleased when the correct order of these interesting deposits shall be finally determined.

Many questions of great geological interest have not been discussed in this report, for the reason that I thought it best to postpone their treatment until some one should have done for the southern half of the Appalachian coal field what I have attempted for the northern half, since the field is a unit from Pennsylvania to Alabama, and in the discussion should be treated as such.

It is hardly necessary to say that the accompanying map is not presented with any claim for accuracy as to details, but only to show in a rough way the general distribution of the different members, and with the hope that it may prove of some service in the preparation of a correct map of these several series when the Survey shall have extended its topographic work over the entire region.

Very respectfully, your obedient servant,

I. C. WHITE.

Hon. J. W. POWELL,
Director U. S. Geological Survey, Washington, D. C.

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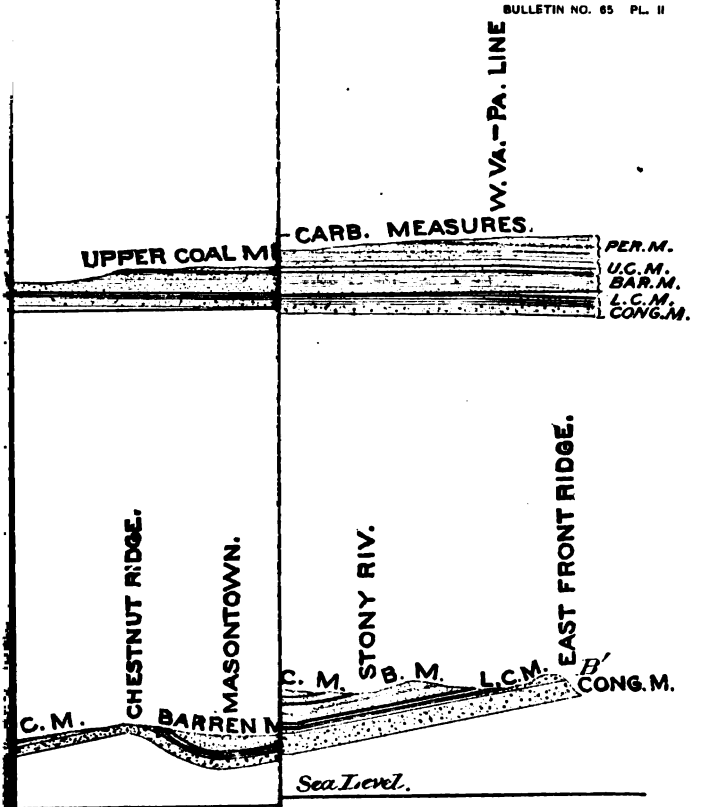

FIG. 1.

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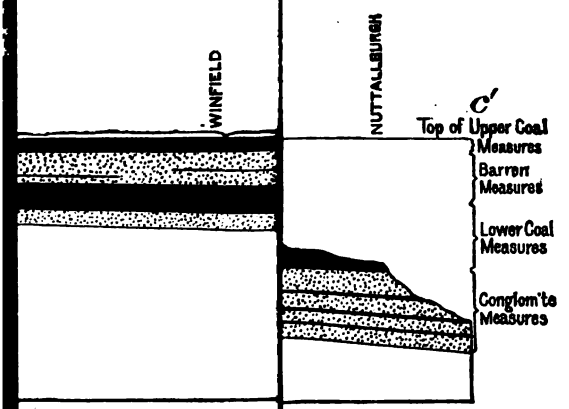

FIG. 2.

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STRATIGRAPHY OF THE BITUMINOUS COAL FIELD IN PENNSYLVANIA, OHIO, AND WEST VIRGINIA.

By I. C. White.

CHAPTER I.

AREA, STRUCTURE, AND CLASSIFICATION.

The Appalachian Basin contains the largest continuous coal field of any Carboniferous area. Beginning near the northern line of Pennsylvania, latitude 42°, longitude 77°, it extends southwestward through West Virginia, southeastern Ohio, eastern Kentucky, and central Tennessee, ending in western Alabama, latitude 33°, longitude 88°, 900 miles from its northern terminus.

The shape of the field has been compared to that of a rude canoe, the pointed ends being in Pennsylvania and Alabama, respectively, while the broadest portion lies in southern West Virginia and Ohio.

As is well known, the general structure of the field is that of a great trough or basin, the line of greatest depth leaving Pennsylvania near its southwest corner, and passing down through West Virginia rudely parallel to the Ohio River, to enter Kentucky 10 miles above the mouth of the Big Sandy River. This general trough or geo-syncline is itself traversed, especially in its northeastern portion, by a series of flexures, which, although so gentle along the region west of the center of the field as to be recognizable with difficulty, yet eastward thereof they increase in amplitude until the great folds of the Alleghany Mountains become a part of the system.

The map sections shown on Pls. X and XI, crossing the Appalachian field nearly normal to the strike, will give the reader a good idea of the structure of the northern half of this field at the localities indicated on the map (Pl. I), and they also show how the folds which are so prominent at the northeast gradually die out toward the southwest, so that in the region of the Great Kanawha River they almost disappear. This flattening out of the flexures in southern West Virginia has been ascribed by Professors Fontaine and Stevenson to the development of the great system of faults along the southeastern margin of the coal field in the edge of Virginia, which relieved the tension on the rocks over

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the adjoining portion of the Appalachian field and thus prevented their folding as in Pennsylvania and northern West Virginia. These anticlinal and synclinal folds so well developed at the north are nearly parallel to the Alleghany Mountains, but as they begin to die away in central West Virginia a large anticline (the Volcano) runs nearly north and south diagonally across the general strike of the beds.

There are probably other folds in the southwestern part of West Virginia, which, like the Volcano anticline, run contrary to the usual direction, but they have not been traced out with sufficient care to warrant description.

The distribution of the different geological groups on the accompanying map will serve to show the general position and direction of the principal anticlines, but the topographic base of the map is so inaccurate that it was thought best not to attempt to put in the anticlinal lines of the region described till the Survey should have completed the regular topographical map.

In this connection it should be stated that this map is not presented with any claims for accuracy in detail, but simply to show the general distribution of the Carboniferous system.

The portion of the Appalachian region herein described includes only the bituminous coal fields of Pennsylvania, Ohio, and West Virginia.

The Pennsylvania and Virginia geologists, led by the two illustrious Rogers brothers, long ago discovered that the main coal-bearing portion of the Carboniferous system could be naturally subdivided into five series. This generalization was founded upon a careful study of the rocks over a wide area, and the subsequent work of other geologists has fully established its general truthfulness to nature as well as its great usefulness in stratigraphic geology.

The more detailed and minute studies of recent years, rendered possible by vast mining developments, have only modified the Rogers classification, and hence it has become so thoroughly ingrafted into geological nomenclature and so familiar to the minds of practical coal operators that it would be very unwise to make any radical changes in it. It is true that in minor details the original nomenclature for some of these series was misleading, but this does not materially affect the grand truths expressed in the general framework of the classification, and hence it has been deemed best to modify and supplement this time-honored work, rather than to destroy it and cast it away, as has recently been suggested by some geologists.

The classification adopted in this report attempts to preserve whatever of the old nomenclature has been found useful and helpful to geologists, while at the same time such new features are introduced as seem necessary from our wider and more intimate knowledge of these rocks.

The entire Carboniferous system of the Appalachian region subdivides naturally into three grand divisions founded upon conditions of accu-

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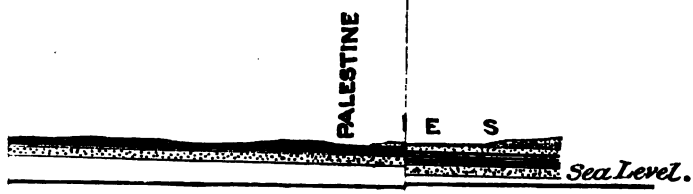

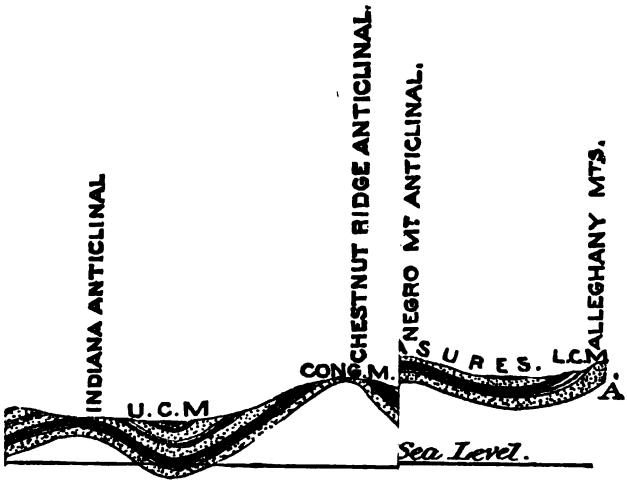

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mulation, and these in turn split up into eight minor series, as exhibited in the following scheme:

	Divisions.	Series.	
CARBONIFEROUS SYSTEM	Upper: fresh and brackish water deposits.	Permo-Carboniferous, No. XVI, Dunkard Creek Series.	
		Upper Coal Measures, No. XV, Monongahela River Series.	
	Middle: shore deposits, with incursions of the sea.	Barren Measures, No. XIV, Elk River Series.	Upper half.
			Lower half.
		Lower Coal Measures, No. XIII, Allegheny River Series.	
		Pottsville Conglomerate Measures, "Great," "Seral," No. XII, Conglomerate, etc.	
	Lower: marine deposits.	Mauch Chunk Red Shale, Umbral Red Shale. Mountain Limestone, Umbral Limestone, Greenbrier, etc.	No. XI.
		Pocono Sandstone, Vespertine, No. X, "Big Injun" oil sand, etc.	

As will be seen from the foregoing diagram, the line between the Middle and Upper Carboniferous deposits passes directly through the center of the Elk River series. This is due to the fact that marine conditions ceased, never to return, with the deposition of the Crinoidal limestone and its associated beds, midway in the Barren Measures, thus separating them into two divisions which are of almost equal thickness, the lower one abounding in marine life, while the upper has nothing but fresh or brackish water forms. The change in this respect is great enough to warrant the separation of the Barrens into two series, but as the lithological differences at the line of separation are very meager, it is deemed best to keep these rocks a unit as in the Rogers nomenclature.

This report deals only with the Middle and Upper Carboniferous of the above table, and the five series into which they are subdivided will now be described in detail, beginning with the highest.

The discussion of many interesting questions connected with Carboniferous geology is necessarily postponed until the rest or southern half of the Appalachian coal field has been carefully studied as a whole.

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CHAPTER II.

THE PERMO-CARBONIFEROUS OR DUNKARD CREEK SERIES.

THICKNESS, CHARACTER, AND EXTENT.

The rocks of this series (Upper Barren Measures, No. XVI) begin with the roof shales of the Waynesburg coal and extend upward to the topmost beds of the Appalachian region.

How many feet of deposits erosion has removed above the highest remaining beds we can only conjecture. However, if the soft and easily yielding character of the rocks which have escaped disintegration can be taken as a criterion for those that have wasted away, the thickness of the latter must be reckoned by the thousand and probably by the 10,000 feet.

Several independent measurements from the highest accessible summits foot up a little more than 1,150 feet for the thickness of the series and it is certain that no other localities could exceed this by more than 100 feet.

The uppermost beds are found at the headwaters of Dunkard Creek, a large stream which heads near the West Virginia-Pennsylvania line, on the eastern slope of the watershed separating the Ohio and Monongahela River drainage system, and flowing eastward puts into the Monongahela two miles above Greensboro, Greene County, Pennsylvania, and four miles north from the West Virginia line. This stream flows over Permo-Carboniferous rocks from its source to the point at which it leaves the West Virginia line at Mount Morris, Pennsylvania, a distance of more than thirty miles, furnishing very fine exposures of these rocks along its banks and bluffs; hence the geographical name (Dunkard Creek) which I have given the series.

These deposits occupy a rather limited area in the Appalachian field, being found in only two counties (Greene and Washington) of Pennsylvania, with the exception of small isolated patches in Fayette, Westmoreland, and Allegheny. In Ohio there is a larger area of them bordering the Ohio River through the counties of Belmont, Monroe, Washington, Athens, Meigs, and Gallia. But it is in West Virginia that we find the principal belt of these beds, for there they cover a wide

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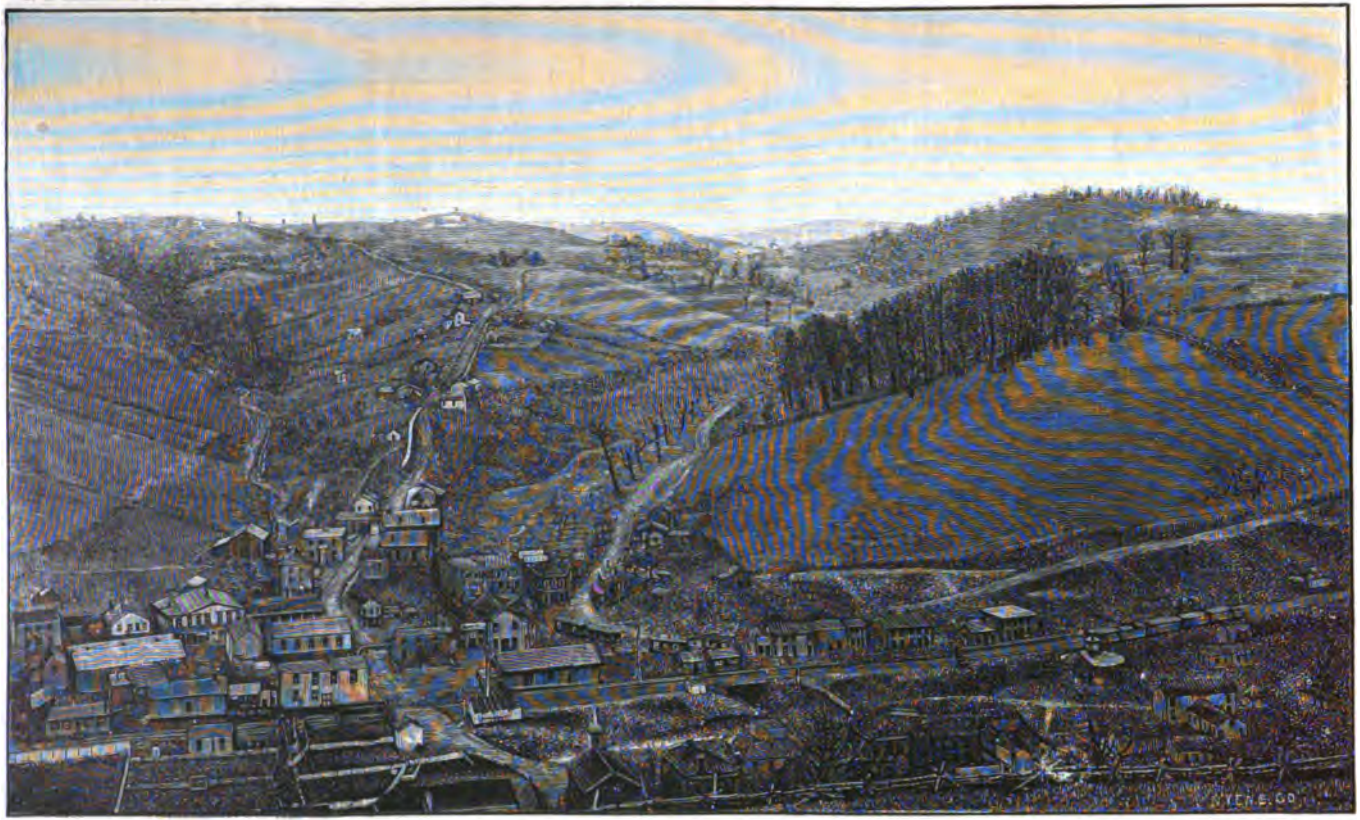

PERMO-CARBONIFEROUS, CAMERON, WEST VIRGINIA.

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region bordering the Ohio River between the Pennsylvania line at the north and the Great Kanawha River on the south, as the accompanying map shows.

The character of the rocks varies greatly in different portions of this area. At the northeastern end of the field, in Washington County, Pennsylvania, limestones seem to predominate in thickness over the gray shales, sandstones, and thin coal beds with which they are there interstratified. But southwestward the limestones and coals gradually disappear, so that in Jackson County, West Virginia, no regular coal beds are found, and only one limestone (the Nineveh) remains. The limestones continue in considerable number in Greene, Ohio, Marshall, and Monongalia Counties, and the northern part of Wetzel County, but southward from this line they rapidly disappear, with the single exception noted. The coal beds all die out with the disappearance of the limestones, except one (the Washington), which seems to extend beyond the Little Kanawha River before it passes out of the series.

As the limestones and thin coal beds gradually fade out to the southwest, red shale, a variety of rock almost unknown in Washington County, Pennsylvania, gradually comes into the section in thin beds at first, but finally extends throughout the whole series, and forms nearly one-half its thickness, thus making a broad band of red soil from the Pennsylvania line southwestward to the Great Kanawha River.

This increase in red shale beds is accompanied by an increase in the number and massiveness of the sandstone rocks, so that the topography gradually becomes greatly different from that found in Washington County, Pennsylvania. There the surface is gently rolling, the valleys broad, and the hills rounded, with no deep gorges or precipitous slopes, the abundance of limestone rendering the soil so highly fertile that the region has long been famed as one of the finest grazing and agricultural districts in the Union. But toward the southwest, while the soil remains very fertile, owing to a large quantity of marly material in the red shales, yet the thickening up of the sandstone beds makes the valleys narrow and the lower portion of the hills often precipitous, the arable land being confined largely to the ridges, so that the soil is better adapted to grazing than tillage. In many cases the massive sandstones crop out along the ridges which they have protected from erosion, forming narrow "hogbacks," from which the surface falls away rapidly on each side. Another peculiarity of these beds is that the sand rocks contain no pebbles except near the base of the series, since above the Waynesburg sandstone no pebbles larger than coarse sand grains have ever been seen by the writer in all of the 1,000 feet of deposits, except at a single locality on the Parkersburg and Staunton turnpike, along the dividing ridge between Ritchie and Gilmer Counties, West Virginia, where locally the Marietta Sandstones, 140 feet above the Washington coal, thicken up into a very coarse conglomerate, filled with quartz pebbles.

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The character of the rocks which compose these measures in the several regions of their area will be seen from the sections which follow.

Section on Dunkard Creek, Greene County, Pennsylvania.—Fig. 1 shows the succession found along Dunkard Creek, from the head of its Pennsylvania fork in Gilmore Township, Greene County, eastward to where the stream veers northward back into Pennsylvania at Mount Morris.

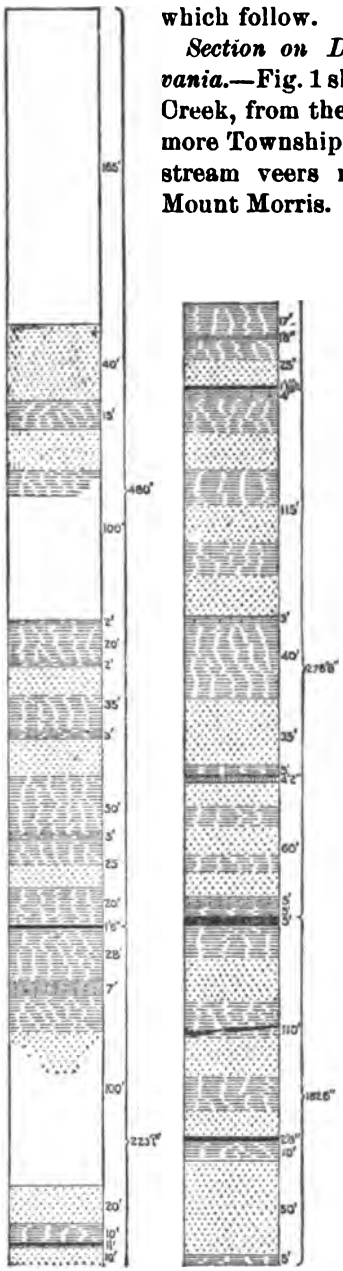

FIG. 1.—Section on Dunkard Creek, Pa.

Dunkard Creek, Greene County, Pennsylvania.

[See map, L l to L k.]

		Ft.	in.	Ft.	in.
1.	Concealed from top of Shough's knob	165			
2.	Sandstone, massive, Gilmore	40			
3.	Shales, with limestone at base	15			
4.	Sandstone and shales and concealed	100			
5.	Shale, red	2			
6.	Shales, gray	20		480	
7.	Shale, marly	2			
8.	Sandstone and shale	35			
9.	Shale, red	3			
10.	Sandstone and shale	50			
11.	Red shale	3			
12.	Shales and sandstone, Nineveh	25			
13.	Shales	20			
14.	Coal, Nineveh	1	6		
15.	Shales	28			
16.	Limestone (No. X), Nineveh	7			
17.	Shales, sandstone and concealed	100			
18.	Sandstone, massive, Fish Creek	20			
19.	Shales with fossil plants	10			
20.	Coal, Dunkard. { Coal.. 0′ 5″; Slate 0′ 1″; Coal.. 0′ 6″ }	1		223	
21.	Limestone	1			
22.	Sandstone	10			
23.	Shales	17			
24.	Limestone, Jollytown	1	6		
25.	Shales and sandstone	25			
26.	Coal, Jollytown	1	1		
27.	Calcareous shale, fossiliferous, fish teeth	0	6		
28.	Limestone, Upper Washington	4			
29.	Shales and sandstone	115			
30.	Limestone, Middle Washington	3			
31.	Shales	40			
32.	Sandstone	35		276	8
33.	Shale	5			
34.	Coal, Washington "A." { Coal, impure. 1′ 2″; Fire clay 2′ 6″; Coal 0′ 6″ }	4	2		
35.	Shales and sandstones	60			
36.	Limestone, Lower Washington	5			
37.	Shales	5			
38.	Coal, Washington, slaty	5			
39.	Shales and sandstones, including a coal bed near center	110			
40.	Coal, Waynesburg, "A"	2	6	182	6
41.	Shales	10			
42.	Sandstone, Waynesburg	50			
43.	Shales, with fossil plants (Cassville)	5			
44.	Waynesburg coal.				
	Total			1,162	3

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Section on Colvin's Run, Greene County, Pennsylvania.—The lower half of this Dunkard Creek series is very finely exposed in a continuous section on Colvin's Run, a tributary of Dunkard which empties into it near Mount Morris, Greene County, Pennsylvania, and in descending this stream the following intervals, as shown in Fig. 2, were carefully measured:

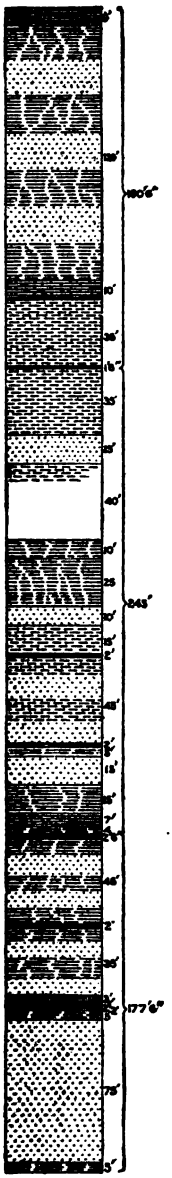

FIG. 2.—Section on Colvin's Run, Pa.

Colvin's Run, Greene County, Pennsylvania.

[See map, L l.]

	Ft.	in.	Ft.	in.
1. Limestone, Nineveh	9			
2. Shales and sandstone	135			
3. Limestone, Jollytown	10		190	6
4. Sandy shales	35			
5. Coal, Jollytown	1	6		
6. Shales, sandy	35			
7. Sandstone, massive	15			
8. Sandy shales and concealed	40			
9. Red shales	10			
10. Shales	25			
11. Sandstone	10			
12. Shales	15			
13. Coaly shales, Washington, "A"	2		245	
14. Sandy shales and sandstone	45			
15. Limestone, gray	2			
16. Shales	5			
17. Sandstone, massive	15			
18. Shales	15			
19. Limestone, Washington Lower	7			
20. Shale, dark	4			
21. Coal, Washington	2	6		
22. Shales and sandstone	45			
23. Coal, Waynesburg, "B"	2			
24. Shales and sandstone	35			
25. Limestone, Colvin's Run	3			
26. Shales	1		177	6
27. Coal, Waynesburg, "A"	2			
28. Limestone	2			
29. Shales	5			
30. Sandstone, Waynesburg	75			
31. Shales, with fossil plants (Cassville)	5			
32. Coal, Waynesburg.				
Total			613	

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Section in Aleppo Township, Greene County, Pennsylvania.—Wheeling Creek rises on the western slope of the Monongahela-Ohio divide, and flowing westward enters the Ohio River at Wheeling. It furnishes excellent exposures of the Dunkard beds from the summit of the series to the base. The following intervals (Fig. 3) were measured along the Dunkard Fork of the creek between its source in Aleppo Township, Greene County, Pennsylvania, and the mouth of Crab Apple Creek, near the West Virginia line:

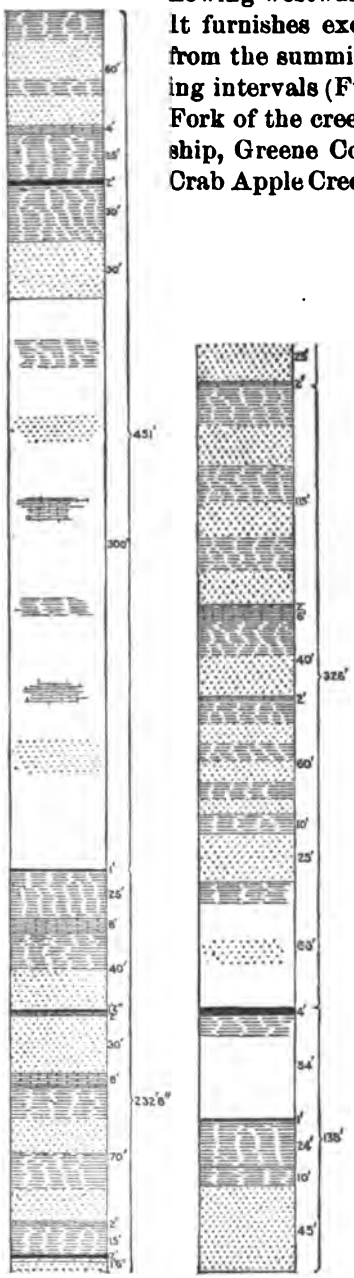

FIG. 3.—Section in Greene County, Pa.

Aleppo Township, Greene County, Pennsylvania.

[See map, L j.]

	Ft.	in.	Ft.	in.
1. Shales and sandstones	60			
2. Limestone, Windy Gap	4			
3. Shale	25			
4. Coal and bituminous shale, Windy Gap	2		451	
5. Shale	30			
6. Sandstone, Gilmore	30			
7. Concealed (shales, sandstones, and limestones)	300			
8. Coal, Nineveh	1			
9. Shales	25			
10. Limestone, Nineveh	8			
11. Shales and sandstone	40			
12. Coal	1	2		
13. Limestone	2			
14. Sandstone	30			
15. Limestone	8		232	8
16. Shales and sandstone	70			
17. Limestone	2			
18. Shale	15			
19. Coal, Dunkard	2			
20. Limestone	1	6		
21. Shaly sandstone	25			
22. Limestone, Jollytown	2			
23. Shales and sandstone	115			
24. Dark, calcareous shale	2			
25. Limestone	6			
26. Shales and sandstone	40			
27. Limestone	2			
28. Shales and sandstone	60		326	
29. Shales	10			
30. Sandstone	25			
31. Shales, sandstones, and concealed	66			
32. Coal, Washington	4			
33. Shales and concealed	54			
34. Coal, Waynesburg, "B"	1			
35. Shales	24		138	
36. Coal, Waynesburg, "A"	0			
37. Shales	10			
38. Sandstone, Waynesburg	45			
39. Coal, Waynesburg.				
Total			1,147	8

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Section at Board Tree Tunnel, Marshall County, West Virginia.—At Board Tree Tunnel, on the Baltimore and Ohio Railroad, and close to the line between Wetzel and Marshall Counties, some very high land occurs, while an oil well boring in the valley of Fish Creek near by carries the rock measurement down to the base of the Dunkard Creek beds. In descending from Rice's Knob past the western portal of Board Tree Tunnel to the Nuce farm oil boring on Fish Creek, and connecting with the record of the latter, the following succession (Fig. 4) is revealed:

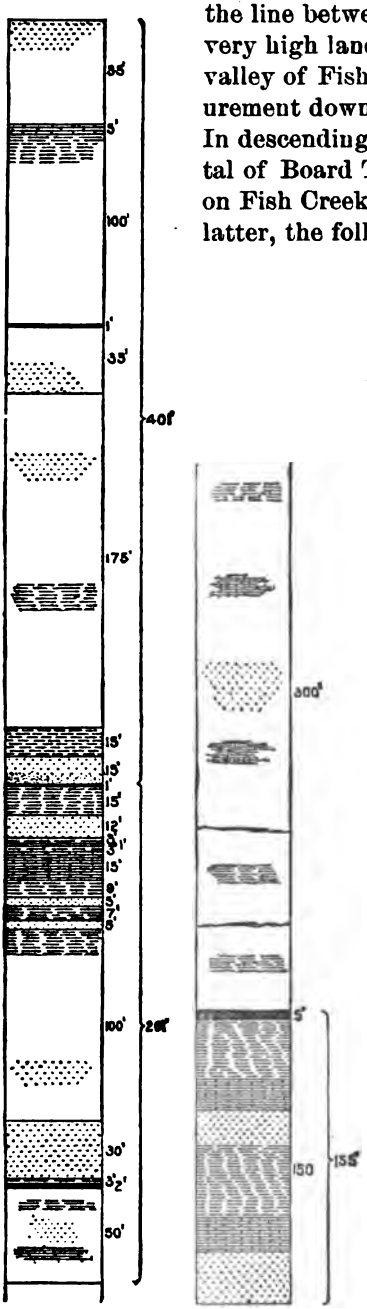

FIG. 4.—Section at Board Tree Tunnel, Marshall County, W. Va.

Board Tree. Marshall County, West Virginia.

[See map, L j.]

	Ft.	Ft.
1. Sandstone, gray, and concealed..	55	
2. Gray limestone, Windy Gap	5	
3. Red shales and concealed	100	
4. Coaly slate.....	1	
5. Concealed to base of a massive sandstone.....	35	401
6. Concealed, sandstone and red shale to Board Tree Tunnel....	175	
7. Sandy shales.....	15	
8. Sandstone, Nineveh.....	15	
9. Coal, Nineveh.....	1	
10. Gray shales	15	
11. Sandstone, massive	12	
12. Shales	3	
13. Limestone Nineveh.. { Limestone... 1'; Black slate.. 3'; Limestone and limy beds ..15' }	19	
14. Variegated shales.....	9	
15. Sandstone	5	
16. Shales, limy.....	7	261
17. Sandstone, to level of track at west portal	5	
18. Concealed shales and sandstone.	100	
19. Massive sandstone, Fish Creek.	30	
20. Shales	3	
21. Coal, Dunkard, to level of bore hole	2	
22. Interval, shales, sandstones, and limestones, with two thin coal beds	50	
23. Shales, sandstones, and red beds.		300
24. Coal, Washington	5	155
25. Shales, limestones, and sandstone.	150	
26. Coal, Waynesburg.		
Total		1,117

There is some uncertainty about the horizon of the Pittsburgh coal in the oil boring, since two large beds are reported, one at 700 feet and the other at 800. The latter is the thicker bed, and as the depth from it to the third oil sand (2,100 feet) agrees with the

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same interval 15 miles to the northeast, I have regarded the lower bed as the Pittsburgh in constructing the above section. If, however, the coal 100 feet higher should prove to be the Pittsburgh, then the 5-foot coal 150 feet above the bottom of the section would probably be the Waynesburg bed, and the Dunkard Creek series should be cut off just above it, and thus shortened by 155 feet at this locality.

In the vicinity of Bellton, Marshall County, West Virginia, 4 miles west from Board Tree Tunnel, the exposures are very fine and the surface outcrops can there also be combined with the record of an oil boring, which thus gives another measurement of the entire series.

Section at Bellton, Marshall County, West Virginia.—In descending from the highest summits near Bellton, the following succession (Fig. 5) is obtained when combined with an oil-boring record which was published by the writer in the Annals of the Lyceum of Natural History, New York, July, 1874:

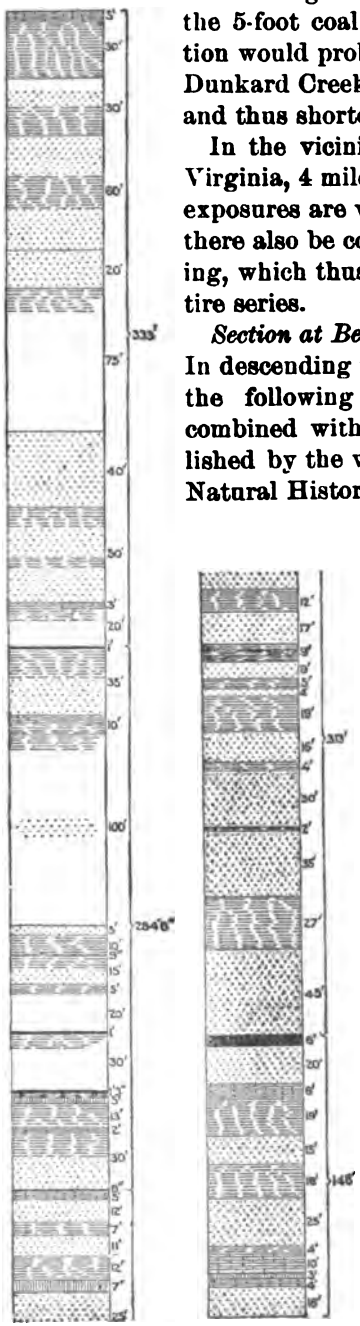

FIG. 5.—Section at Bellton, W. Va.

Bellton, Marshall County, West Virginia.

[See map, L j.]

	Ft.	Ft.	in.	
1. Limestone, Windy Gap	5			
2. Shales	30			
3. Coal, Windy Gap, blossom	0			
4. Concealed and sandstone and shales	30			
5. Shales and sandstone	60			
6. Sandstone, massive, gray	20			333
7. Red shales and concealed	75			
8. Sandstone, massive	40			
9. Red shales and sandstone	50			
10. Limestone	3			
11. Shales and concealed	20			
12. Coal, Nineveh	1			
13. Shales and sandstone	35			
14. Limestone and shales, Nineveh	10			
15. Shales, sandstone and concealed	100			
16. Sandstone	5			
17. Shales	10			
18. Limestone	0	6		
19. Coal	0	3		
20. Shales and sandstone	15			
21. Red shales	5			284 8
22. Concealed	20			
23. Coal	1			
24. Shales and concealed	30			
25. Coal, Dunkard { Black slate 4″ Coal 11″ }	1	3		
26. Limy shales and fire clay	5			
27. Shales	13			
28. Limestone, gray, Jollytown	2			
29. Shales and sandstones	30			
30. Coal, Jollytown	0	8		
31. Limestone, gray, Upper Washington (continued from oil-well record)	5			
32. Sandstone	12			
33. Shale	7			
34. Sandstone	11			
35. Shale	12			
36. Fire clay	7			
37. Sandstone	25			
38. Shale	12			
39. Sandstone	17			

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	Ft. in.	Ft. in.
40. Coaly shales	9	
41. Sandstone	9	
42. Shale	5	
43. Sandstone	4	
44. Shale	19	
45. Sandstone	16	
46. Shale	4	313
47. Sandstone	30	
48. Shale	2	
49. Sandstone	35	
50. Shale	27	
51. Sandstone	45	
52. Coal, Washington	6	148
53. Sandstone	20	
54. Limestone	8	
55. Shale	19	
56. Sandstone	15	
57. Shale	18	
58. Sandstone	25	148
59. Shale	4	
60. Limestone	10	
61. Fire clay	3	
62. Limestone	4	
63. Sandstone	16	
64. Place for Waynesburg coal.		
Total		1,078 8

This boring did not reach the Pittsburgh coal, and hence the identification of the 6-foot coal bed, 142 feet above the base of the section, is made on the same basis as that of the 5-foot bed 150 feet above the bottom of Section 4, since the two coals are evidently identical. The thin coals in the upper half of the series have been named the Bellton group from this locality.

Section at New Martinsville, West Virginia.—In passing southwestward from this area of maximum development of the Permo-Carboniferous rocks a considerable change takes place in the character of the beds. The Bellton coal group practically disappears, and also many of the limestones, so that in the vicinity of New Martinsville, Wetzel County, West Virginia, the lower half of the series presents the structure shown in Fig. 6:

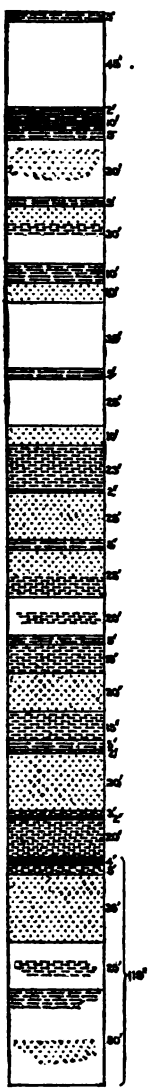

FIG. 6.—Section at New Martinsville, W. Va.

New Martinsville, Wetzel County, West Virginia.

[See map, M i.]	Ft.	Ft.
1. Red shale		5
2. Concealed		45
3. Red shale		2
4. Limestone, Nineveh, in several layers separated by shale		10
5. Red marly shale		5
6. Concealed and sandstone		30
7. Red shale		5
8. Sandstone, sandy shales, and concealed		30
9. Red shale		10
10. Sandstone, massive		10
11. Concealed		35
12. Red shale		5
13. Concealed		25
14. Sandstone, brown massive		10
15. Sandy shales		23
16. Red shale		2
17. Sandstone		25
18. Red shale		5
19. Sandstone and sandy shales		25
20. Concealed and sandy shales		20
21. Red marly shales, with limestone nodules		5
22. Sandy shale, gray		15
23. Sandstone, massive		20
24. Sandy shales		15
25. Red shale with limestone nodules		5
26. Shale, gray, sandy		2
27. Sandstone, massive		30
28. Sandy shales		3
29. Limestone, impure		2
30. Sandy shales		20
31. Coal, Washington	4	
32. Sandy shales	5	
33. Sandstone, massive	35	119
34. Concealed and sandy shales	25	
35. Shales, sandstones, and concealed	50	
36. Waynesburg coal.		
Total		563

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No. 4 appears to represent the Nineveh limestone, though its interval above the base of the series is less here than usual.

Not a single one of the Bellton coals was observed in this section, though some of them may have been present and concealed.

Section at Baresville, Ohio.—In the vicinity of Baresville, Monroe County, Ohio, a long section was made by the late Prof. E. B. Andrews. It is referred to in vol. II, Ohio Geology, page 587, and published on Map XIII, section No. II. The locality is only 1½ miles above New Martinsville, West Virginia, and the succession reads as follows (Fig. 7):

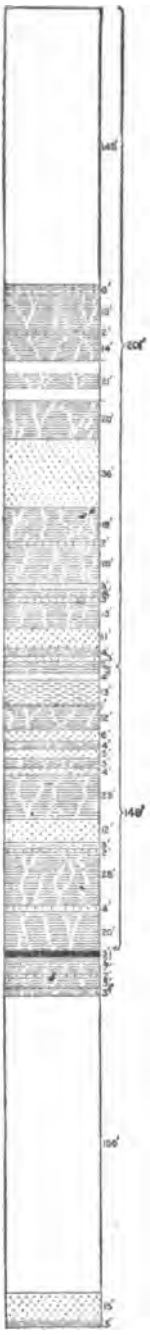

FIG. 7.—Section at Baresville, Ohio.

Baresville, Monroe County, Ohio.

[See map, M 1.]

		Ft.	in.		
1.	Coal, blossom				
2.	Concealed			145	
3.	Limestone, Nineveh	6			
4.	Shale	18			
5.	Limestone, sandy	2			
6.	Red shale	14			
7.	Shale, mostly	21			
8.	Shale	20			
9.	Sandstone, laminated	36			
10.	Red shale	18			
11.	Sandstone	2			
12.	Red shale	20		201	
13.	Sandstone	3			
14.	Shale	4			
15.	Sandstone	3			
16.	Red shale	13			
17.	Sandstone	11			
18.	Shale	4			
19.	Sandstone	3			
20.	Shale	3			
21.	Coal, blossom, Jollytown				
22.	Shale	3			
23.	Sandstone	4			
24.	Sandy shale	13			
25.	Sandstone	1			
26.	Shale	12			
27.	Sandstone	6			
28.	Shale	4			
29.	Sandstone	5			
30.	Shale	5		149	
31.	Sandstone	4			
32.	Shale	23			
33.	Sandstone	12			
34.	Shale	3			
35.	Sandstone	2			
36.	Shale	28			
37.	Sandstone	4			
38.	Shale	20			
39.	Coal, Washington "A". { Coal 0′ 9″; Clay 0′ 4″; Coal 2′ 0″ }			3	1
40.	Clay			2	
41.	Shale			7	
42.	Sandstone			2	
43.	Shale			5	
44.	Sandstone			1	
45.	Shale			3	
46.	Concealed			156	
47.	Sandstone, Waynesburg			15	
48.	Shale			3	
49.	Coal, Waynesburg.				
	Total			692	1

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The coal blossom at the summit of Section 7 appears to come at a horizon above any of the Bellton beds, and hence is a new and probably extremely local element in the series.

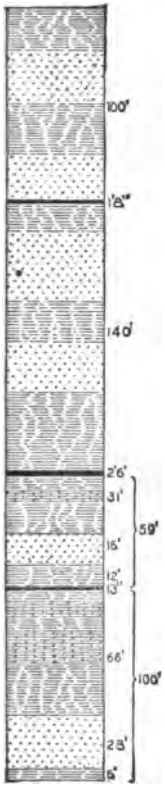

Fig. 8.—Section in Washington County, Ohio.

Section in Liberty Township, Washington County, Ohio.—The following (Fig. 8) succession of the beds in the lower portion of this series is reported by Mr. F. W. Minshall from a hill near the Epler oil-boring in Liberty Township, Washington County, Ohio:

Liberty Township, Washington County, Ohio.

[See map, M g.]	Ft.	Ft.	in.
1. Shales and sandstones		100	
2. Coal, Jollytown		1	8
3. Shales and sandstone		140	
4. Coal, Washington "A"		2	6
5. Shales and limestone	31		
6. Sandstone	16	59	
7. Shales	12		
8. Coal, Washington		1	3
9. Limestone and shales	66		
10. Sandstone, pebbly, Waynesburg	28	100	
11. Shales	6		
12. Waynesburg coal.			
Total		404	5

These identifications are made on the supposition that the Macksburg coal of the Ohio geologists is the equivalent of the Waynesburg bed.

Section at Washington, Pennsylvania.—In Washington County, Pennsylvania, the Dunkard series, as al already stated, contains much more limestone than elsewhere, and the intervals between the several members are somewhat less than in Greene County. The following section (Fig. 9) from Geological Survey, Pennsylvania, Report K, page 248, exhibits the structure of the lower portion of these beds at Washington, Pennsylvania:

Washington, Pennsylvania.

[See map, J l.]	Ft.	in.	Ft.	in.
1. Limestone, Jollytown			10	
2. Shale			5	
3. Coal, Jollytown			1	
4. Sandstone	10			
5. Dark shale	8			
6. Limestone, Upper Washington	30			
7. Concealed	50		190	
8. Coal, blossom	0			
9. Concealed	80			
10. Limestone, Lower Washington	12			
11. Coal, Washington	7			
12. Clay	4			
13. Sandstone	9			
14. Concealed	10			
15. Limestone	2		117	6
16. Shales, limestone, and concealed	65			
17. Black slate	1	6		
18. Limestone	4			
19. Blue shale	15			
20. Waynesburg coal.				
Total			323	6

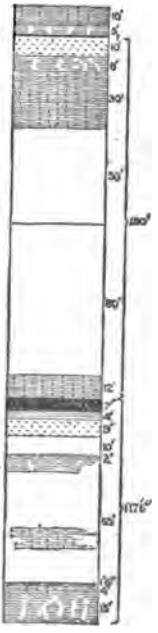

Fig. 9.—Section at Washington, Pa.

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Section near Taylorstown, Pennsylvania.—Another section, from the same volume page 259, exhibits the succession in the lower half of this series in Buffalo Township, Washington County, Pennsylvania, as shown in Fig. 10.

In both these sections (9 and 10) the writer has changed the identifications of some of the beds (notably that of the Jollytown coal) from that made in the original sections by Stevenson, but in every such case the change is clearly warranted, since the coal in question was placed too near the Washington coal by Stevenson.

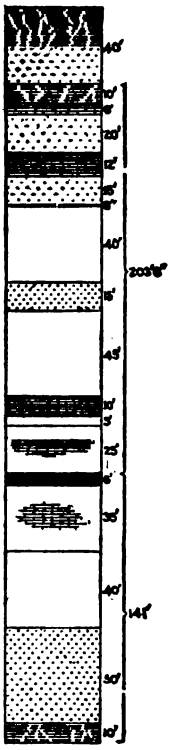

FIG. 10.—Section near Taylorstown, Pa.

Near Taylorstown, Washington County, Pennsylvania.

[See map, J k.]

	Ft.	in.	Ft.	in.
1. Limestone, in fragments			0	
2. Shales and sandstone			40	
3. Coal, blossom, Jollytown	0			
4. Shale	10			
5. Limestone	6			
6. Concealed	20			
7. Limestone	12			
8. Sandstone	15			
9. Coal	0	8		
10. Concealed	40			
11. Limestone	15		203	8
12. Concealed	45			
13. Limestone	10			
14. Concealed	5			
15. Coal	0			
16. Concealed, with much limestone	25			
17. Coal, Washington	6			
18. Concealed, with a limestone	35			
19. Coal, blossom, Waynesburg "B"	0			
20. Concealed	40			
21. Coal, blossom, Waynesburg "A"	0		141	
22. Waynesburg sandstone	50			
23. Shales	10			
24. Coal, Waynesburg			0	
Total			384	8

The very highest beds of the Dunkard Creek series known to the writer occur in Shough's Knob, at the head of Dunkard Creek, Gilmore Township, Greene County, Pennsylvania, but these are concealed by a thick covering of soil, and hence could not be seen in detail. The highest rock of the series which has been traced over any considerable area is the Windy Gap Limestone.

CHARACTERISTIC HORIZONS.

THE WINDY GAP LIMESTONE.

This has been named from its occurrence near Windy Gap, a "divide" separating the Laurel Run branch of Fish Creek from the waters of Wheeling Creek, in Springhill Township, Greene County, Pennsylvania.

The stratum is usually of a bluish gray color, quite pure, and has a thickness of about five feet. It contains minute fresh water fossils, and occasionally small crystals of blende.

The only land geologically and topographically high enough to catch this stratum is that which clusters about the southwestern corner of Pennsylvania, in Greene County, and the adjoining regions of Marshall, Wetzel, and Monongalia, in West Virginia. Only one point (Hunsucker's Knob) in the last county is high enough to catch this limestone, since its outcrop ranges between 1,500 and 1,600 feet above the sea. The sections (Figs. 3 and 4) at Board Tree and Bellton, in Marshall County, as well as the one (Fig. 2) in Aleppo Township, Greene County, show this stratum near their summits, but its horizon is concealed in Shough's Knob of the Dunkard Creek section (Fig. 1).

This is the same stratum as that numbered Limestone XIV by Prof. John J. Stevenson in his Report K, Second Geological Survey of Pennsylvania.

THE WINDY GAP COAL.

At an interval of 25 to 30 feet below the limestone just described there occurs a small coal bed just under the summit of the "divide" at Windy Gap, Greene County, Pennsylvania, and it has been designated from that locality. No opening into it has ever been made, and hence it is known only as a blossom which exposes one to two feet of coal and black slate, the latter filled with the fossil Cypris, or a closely allied form.

The same bed was also seen in Aleppo Township, and in the summit of the hills at Bellton. It is the highest known coal of the series, and comes about 1,050 feet above the Waynesburg bed.

THE GILMORE SANDSTONE.

Crowning the upper portion of the Permo-Carboniferous beds over a considerable area around the heads of Dunkard, Wheeling, and Fish Creeks, there occurs a very massive sandstone having a thickness of 25 to 40 feet. It was named the Gilmore sandstone by Professor Stevenson, from its occurrence in the township of that name in southwestern Greene County. This stratum is usually a coarse and very massive sandstone, excellent for building purposes, and often forming long lines of cliffs on the summits of the high ridges. These cliffs are always traversed with fissures, and they furnish a convenient retreat for foxes when chased by hounds, so that the stratum in question is often locally known as the "Fox rocks," and again it is named from the farms where the cliffs occur, as "Pethtle" rocks, "Efaw" rocks, etc. This stratum has been the main agency in preserving all of the very high beds of the Permo-Carboniferous from erosion.

The interval below the Gilmore sandstone for 200 to 250 feet consists of red shales, occasional thin limestones, and gray sandstones, but con-

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tains no beds sufficiently characterized to be identifiable over any considerable area.

THE NINEVEH SANDSTONE.

At 225 to 250 feet below the Gilmore sandstone, we come to another great sandstone deposit which, from its good development near the village of Nineveh, Greene County, Pennsylvania, has been designated from that locality. Like the Gilmore sandstone above, it is usually an excellent building stone, and has long been used for that purpose on the Baltimore and Ohio Railroad, near Littleton, Wetzel County, West Virginia, where it crops out in a great cliff along the hills 150 to 200 feet above creek level.

This same stratum may also be seen in the hills two miles above Jollytown, Greene County, where it has long been quarried on the land of Thomas White for building purposes. It is of a yellowish gray cast, rather coarse-grained, but soft, and splits readily into rectangular blocks.

THE BELLTON COAL GROUP.

At 275 to 300 feet under the Gilmore sandstone we find the uppermost of a series of thin coals which, from their fine exposure at the village of Bellton, Marshall County, West Virginia, have been termed the Bellton group. These coals, few of which are rarely more than one foot thick, occur within a rock interval of 200 to 300 feet, and when all are present, as in the Bellton section (Fig. 5), there are five distinct beds, though not all of them are persistent over any considerable area. The three beds given in the Dunkard Creek section (Fig. 1), viz, the Nineveh, Dunkard, and Jollytown coals, are the most important members of the group. Interstratified with these coals are shales, sandstones, and two important limestones.

THE NINEVEH COAL.

This is the uppermost member of the Bellton group, and was named from the village of Nineveh, Greene County, Pennsylvania, by Professor Stevenson.

The coal rarely exceeds one foot in thickness, yet it is generally quite pure, and is frequently used for smithing purposes.

In the hills at Bellton it crops out 290 feet above Fish Creek, and the same coal is seen in the railroad cut at the western portal of Board Tree Tunnel, 75 feet above track level.

On the head waters of Dunkard Creek it is known as the John Taylor coal, and although only one foot thick is highly valued as a smithing fuel.

THE NINEVEH LIMESTONE.

Below the Nineveh coal at an interval of 25 to 30 feet there comes a limestone which has a very extended distribution. It was called Limestone No. X by Professor Stevenson in his Report K, Greene and Wash-

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ington Counties, but it is here designated from the same village in Greene County which has given name to the coal and sandstone already described.

This limestone usually consists of several layers separated by shales the whole of which sometimes foots up nearly 20 feet, as in the section at Board Tree Tunnel (Fig. 4), but its usual thickness is seldom more than 10 feet. Frequently a stratum of bituminous shale is found interstratified with the layers of limestone. Some of the latter are quite pure, and furnish excellent lime. It has a very wide distribution, as may be seen from its presence in each of the first seven sections already given. The same stratum extends clear through to Jackson County, West Virginia, and nearly to the Big Kanawha River, where it occurs high up on the summits of the hills and is hence termed the "Ridge" limestone, by the farmers.

There is a fine exposure of this rock at Limestone Hill Post-office, on the Parkersburg and Charleston turnpike, near the corners of Wirt, Wood, and Jackson Counties, West Virginia. It is there nearly 30 feet thick, in several layers, and contains many minute fossils, all apparently of fresh-water types.

THE HOSTETTER COAL.

Occasionally a bed of coal occurs at 75 to 100 feet below the Nineveh limestone. It has been stripped out of the run on the old Hostetter farm near Burton, Wetzel County, West Virginia, where it is 12 to 15 inches thick and rather pure. It also appears to be present in some localities near the head of Dunkard Creek, and in a local section near Bellton it was seen 15 inches thick at 130 feet below the Nineveh coal.

THE FISH CREEK SANDSTONE.

At 135 to 150 feet below the Nineveh coal, there often occurs a very massive sandstone. It makes the great cliffs along the waters of Fish Creek in Springhill Township, Greene County, Pennsylvania, and was designated from this stream by Stevenson in his Report K.

The rock in question is frequently quite massive, and it makes an excellent building stone. It is very conspicuous in the region of Deep Valley, Pennsylvania, where it forms long lines of vertical cliffs 25 to 30 feet high. It may also be seen in cliffs along the Baltimore and Ohio Railroad, above Littleton, in Wetzel County, where it is quarried for building purposes.

THE DUNKARD COAL.

Below the Fish Creek sandstone, at an interval of 1 to 20 feet, another coal bed is often found, which, from its occurrence along the bed of Dunkard Creek for a considerable distance, was named the Dunkard coal by Professor Stevenson. It is seldom more than 12 to 15 inches thick, but is almost invariably double, having a thin layer of slate near its

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center. At Deep Valley, Pennsylvania, however, this parting thickens up to five feet or more and thus separates the coal into two well-defined beds, each of which is 8 to 10 inches thick. In the roof shales of this coal at Mr. Lee Garrison's, in Gilmore Township, Greene County, Pennsylvania, finely preserved fossil plants abound, principally of the genera Neuropteris and Odontopteris.

This bed is frequently stripped along the streams for local use in Greene, Monongalia, Wetzel, and Marshall Counties.

THE JOLLYTOWN LIMESTONE.

Below the Dunkard coal, at an interval of 25 to 30 feet, there occurs a bed of limestone which is rather persistent. It is well exposed in the vicinity of Jollytown, Greene County, Pennsylvania, and has been designated from that locality. As may be seen from its presence in Sections 1 to 5 and also in 9, this limestone has a wide distribution, though at the head of Dunkard (Fig. 1), and on Fish Creek (Fig. 5), the stratum is only 1 to 2 feet thick. In Washington County, Pennsylvania, however, it thickens up to 10 feet or more and is usually a rather pure limestone.

THE JOLLYTOWN COAL.

This is the lowest member of the Bellton coal group, and underlies the Jollytown limestone by an interval of 25 to 30 feet. The coal was named by Professor Stevenson from a village in Greene County, Pennsylvania.

This is the only coal of the Bellton group that ever attains dimensions of 2 to 3 feet, and can therefore be mined by drifting, since in the vicinity of Wise, Monongalia County, West Virginia, and below this along the South Fork of Dunkard Creek, it is nearly 3 feet thick, and is mined to a considerable extent for local use. The coal is not very pure, but in the absence of any other beds it finds a ready market. In the Bellton section (Fig. 5) this coal has been identified with the lowest bed exposed there. This is only a few inches thick and quite slaty, so that it is possible the Jollytown bed is the one next above, and which in that section has been referred to the Dunkard coal.

Along Dunkard Creek the Jollytown coal is nearly always present, and seldom less than 1 to 2 feet thick. It becomes a very important key rock over a wide region, since there are seldom any other coals below it for an interval of 250 feet. It extends almost without a break across Greene, Monongalia, Marion, and Harrison Counties, but appears to thin away in Doddridge.

Throughout Monongalia, Greene, and Marshall Counties, the interval between this bed and the Washington coal below is about 275 feet, but westward, in Washington County, Ohio (Section 8), the interval thins away to 200 feet, and practically the same measurement is found in Washington County, Pennsylvania (Sections 9 and 10).

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THE UPPER WASHINGTON LIMESTONE.

Three limestones were named from Washington, Pennsylvania, by Professor Stevenson—an Upper, Middle, and Lower one—and two of these are shown in the section (Fig. 9) from the typical locality.

The Upper Limestone is a very important bed in Washington County, since it has a thickness of 20 to 30 feet, and is generally very pure. It is usually of a dark blue color, and is much used for macadamizing roads and burning for agricultural and other purposes. This rock appears to be identical with the limestone seen in the bed of Dunkard Creek near the mouth of Negro Run, above Jollytown, Greene County, Pennsylvania, where it carries a bituminous shale on its top, filled with fish remains and other minute fossils, and underlies the Jollytown coal.

In the bed of Fish Creek at Bellton, Marshall County, West Virginia, we find a limestone with a fish bed on its top, which appears to be identical with the Upper Washington deposit.

THE MIDDLE WASHINGTON LIMESTONE.

About midway in the interval between the Upper Washington limestone and the Washington coal there is frequently found another limestone bed. It is very persistent in Washington County, Pennsylvania, and is often 15 to 20 feet thick and of a buffish color.

On Dunkard Creek it appears to be represented by a stratum seen just above the road at Kent's Mills, where it is only three feet thick. This limestone, like all of those in the Dunkard series, contains minute, undetermined fossils, and the bituminous shales accompanying them hold plenty of fish scales, teeth, etc., as well as fragments of plants.

WASHINGTON "A" COAL.

At 70 to 80 feet above the Washington coal, there occurs a bed of impure coal and coaly shale which is often present in the section along Dunkard Creek. Sometimes the entire bed is four to five feet thick, but little of it is ever merchantable coal, being seldom more than a bituminous slate. It is well exposed in the hills about Blacksville, and Brownsville, in Monongalia County, and there contains many bivalve crustaceans.

Bituminous shale is often found at this horizon in Washington and Greene Counties, Pennsylvania, and in Washington County, Ohio (Fig. 8), a coal bed 2½ feet thick seems to occur at the same place in the series.

THE MARIETTA SANDSTONES.

The Washington "A" coal is often absent, and the portion of the series for 100 to 125 feet above the Washington coal is then frequently occupied by two or three beds of massive sandstone. These crop out in the hills below Marietta, Ohio, where they have long been extensively quarried for grindstones and building stone, and they have been

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designated from that locality. There are often three of them, each 25 to 40 feet in thickness, and separated by thin shales, so that in such cases they might be called the Upper, Middle, and Lower Marietta sandstones. Sometimes, however, as near Rock Lick, Marshall County, West Virginia, the shales thin out and let all of the sandstones coalesce into one mass more than 100 feet thick.

These beds form the great cliffs at Raven Rock, Pleasants County, West Virginia. The upper one is extensively quarried at the Jackson quarry in Parkersburg, West Virginia, and it with its associated rocks forms long lines of cliffs up the Little Kanawha River, where they have been extensively quarried in the vicinity of Elizabeth and other points.

It is one of these beds that makes the big cliffs on the hill above the famous McGugan gas well in Washington County, Pennsylvania. These rocks are sometimes gray, but more frequently of a yellowish or buffish cast, and moderately coarse in grain. They also occur in Ritchie, Wirt, Jackson, and Putnam Counties, West Virginia, where they cap the narrow ridges in long lines of cliffs.

In Greene and Washington Counties, Pennsylvania, and Monongalia County, West Virginia, this interval of 100 feet above the Washington coal is generally occupied by shales, limestones, and thin, sandy beds, massive sandstones being exceptional.

THE BLACKSVILLE LIMESTONE.

In some portions of Washington, Greene, and Monongalia Counties, a limestone occurs with considerable persistency at 30 to 50 feet above the Washington coal. This was numbered Limestone III by Professor Stevenson in his Greene and Washington report, but as it comes to the surface near the bed of Dunkard Creek, in the village of Blacksville, Monongalia County, West Virginia, it has been given a geographical name from that locality. The rock is generally gray, quite pure, and only three to five feet thick. It is seen in Section 2 at 46 feet above the Washington coal. It soon disappears southward from the Pennsylvania line.

THE LOWER WASHINGTON LIMESTONE.

At Washington, Pennsylvania, a limestone of unusual thickness (20 feet) forms the roof of the Washington coal, and it was designated, from that locality, the Lower Washington limestone by Stevenson. It has a wide distribution in Greene, Washington, Ohio, Belmont, Marshall, and Monongalia Counties, but disappears southward from these. It often attains a thickness of 20 to 30 feet in Washington County, but is always interstratified with much shale, and outside of Washington County is seldom more than 5 to 10 feet thick. Frequently some of the layers contain so much carbonate of iron as to prove a fair ore. These iron-bearing layers are often interstratified with bituminous shales, and in such cases the iron layers are covered with fossil plants. It is on

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these thin, shaly layers of carbonate of iron in the roof of the Washington coal at Brown's Bridge, Dunkard Creek, on the West Virginia-Pennsylvania line, that the Permian plant, *Callipteris conferta*, occurs as described in Report PP, Second Geological Survey, Pennsylvania, page 54.

THE WASHINGTON COAL.

This bed, which is the only one in the Dunkard series that is workable over a wide area, was first described by the writer, and named the Brownsville coal from its occurrence at the village of that name in Monongalia County, West Virginia. Subsequently, however, the same coal was found in greater development at Washington, Pennsylvania, and it was designated from that locality by Professor Stevenson.

It is always a multiple bed, being separated into two or three layers by divisions of slate. Occasionally these divisions are numerous and the entire thickness of the bed is 8 to 10 feet, but in all cases the only pure or merchantable coal is the bottom portion, which seldom exceeds two and a half to three feet. The upper part of the bed is nearly always very impure, since it contains so much ash and slate as to constitute it a mere bed of richly bituminous shale.

This coal is much more persistent than any other coal of the Permo-Carboniferous series, since it occurs everywhere in the northern area of these rocks, and does not disappear to the southwest except beyond the Little Kanawha River, in West Virginia, while in Ohio it seems to be persistent even to the southwestern margin of these deposits. In Washington and Meigs Counties, Ohio, it is frequently referred to by Professor Andrews as the Hobson coal.

Section at Farmington, Marion County, West Virginia.—The following section of this coal, taken near Farmington, Marion County, West Virginia, well illustrates the structure of the bed when it is thick:

	Ft.	in.	Ft.	in.	Ft.	in.
1. Coal	0	6				
2. Shale	0	3				
3. Coal and shale	0	8				
4. Coal	1	0				
5. Shale	0	4				
6. Coal	0	5	6	1		
7. Shale	0	3				
8. Coal	1	0				
9. Shale	0	4			10	9
10. Coal	1	1				
11. Shale	0	3				
12. Coal, fair	2	0				
13. Slate	0	2	4	8		
14. Coal, good	2	6				

Here the upper or roof portion of the coal, although 6 feet thick, is entirely worthless, and the only really good coal in the bed is the 2½ feet at the bottom.

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Through Washington County, Pennsylvania, this coal has a thickness of 5 to 6 feet, but very little of it is merchantable.

It is frequently exposed along the Ohio River hills between Wheeling and Parkersburg, being at low water in the latter town.

Before disappearing to the southwest it dwindles down in thickness very much, since at Harrisville, Ritchie County, it is only 2 feet thick, and at the Grahamite mines, near Hughes River in the same county, only 1½ feet.

It is mined for local supply in the vicinity of Smithville, Ritchie County, where it is only 15 inches thick and 150 feet above the level of Hughes River.

Section on Willey Fork, Wetzel County, West Virginia.—At the mouth of the Willey Fork of Fishing Creek, Wetzel County, West Virginia, this coal is brought a few feet above water level by a low, anticlinal roll, and there it exhibits the following structure:

	Ft.	in.	Ft.	in.
1. Dark shales				
2. Coal	0	5	8	2
3. Coaly shale	1	6		
4. Shale, gray, sandy	2	0		
5. Coal	0	3		
6. Gray shales	2	0		
7. Coal, slaty	2	0		

Section near Brown's Mills, Monongalia County, West Virginia.—Near Brown's Mills, Monongalia County, where this coal was first described, it has the following structure:

	Ft.	in.	Ft.
1. Bituminous shale	2	0	8
2. Coal, impure	1	9	
3. Shale	0	4	
4. Coal, slaty	1	4	
5. Shale	0	3	
6. Coal, good	2	4	

At this locality the Lower Washington limestone forms the roof above the bituminous shale No. 1, and it also contains much iron.

Occasionally a thin coal is found resting immediately on top of the Lower Washington limestone, and that condition of affairs exists at Brown's Mills, where a bed of coal and black slate, in all 2 feet thick, occurs 10 feet above the top of the Washington coal. The bed is not persistent enough to merit a separate name, however.

THE WASHINGTON SANDSTONE.

Very frequently no fire clay is present under the Washington coal, and the latter rests directly upon a flaggy sandstone, often finely laminated, brown, micaceous, and containing vegetable fragments in great quantity. This stratum, which was called the Washington sand-

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stone by Professor Stevenson, occurs over a wide area in Monongalia, Greene, and Washington Counties, but is not persistent very far south of the Pennsylvania line.

THE LITTLE WASHINGTON COAL.

Just under the Washington sandstone, and 10 to 20 feet below the Washington coal, there sometimes occurs a thin bed of coal, seldom attaining a foot in thickness. It is more persistent in Washington County, Pennsylvania, than elsewhere, and hence was designated as above by Stevenson. It is seldom seen south from the Pennsylvania line, and in Greene County even is represented only by a thin bed of bituminous slate.

THE WAYNESBURG "B" COAL.

Below the last little coal bed there usually occur shales, thin sandstones, and occasionally a limestone, down to about 45 feet below the Washington coal, where another small bed is found quite persistent in Monongalia, Greene, and Washington Counties. It is seldom more than a foot thick, but sometimes attains to two. It has never been seen south of Monongalia County, and is of little economic importance.

THE COLVIN'S RUN LIMESTONE.

Below the last coal come 30 to 35 feet of shale and thin sandstones, and then we get a limestone that was numbered Limestone I(a) by Professor Stevenson, but I have given it the above geographical designation from its occurrence at the locality of Section 2, where it is 3 feet thick and quite pure. It is often of a buffish cast, however, and contains too much iron to slake well on burning. In Washington County, Pennsylvania, this stratum thickens up to 8 and 10 feet, but it is seldom seen south of the Pennsylvania line.

THE WAYNESBURG "A" COAL.

This occurs just under the last mentioned limestone and like it is confined to the northern end of the Permo-Carboniferous area. It sometimes attains a thickness of 3 and 4 feet, but is generally slaty and worthless, so that it has seldom been mined. It occurs quite generally across Monongalia, Marion, and Harrison Counties, and is possibly present in Ritchie County near Harrisonville, but beyond that it has not been identified. Its horizon is usually 60 to 80 feet above the Waynesburg coal proper.

THE MOUNT MORRIS LIMESTONE.

Separated from the coal last described by only 2 to 5 feet of clayey shales there sometimes occurs a limestone which, although noted, was not named by Stevenson in his Report K. It is well exposed on the north bank of Dunkard Creek at Mount Morris, Greene County, Pennsylvania, and has been designated from that locality. The stratum

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is often only 1 to 2 feet thick, and seldom more than 5 feet except in Washington County, Pennsylvania, where it is occasionally thicker.

This limestone is not persistent, and is seldom found south of the Pennsylvania line, being frequently absent even in Greene and Washington Counties.

THE WAYNESBURG SANDSTONE.

Just under the horizon of the Mount Morris limestone, and separated from it by 2 to 5 feet of shales and clay, there comes a very important sandstone. This was long ago termed the Waynesburg sandstone, from its fine development near the town of that name in Greene County, Pennsylvania. It is one of the most persistent members of the Permo-Carboniferous series, since its eastern outcrop can be followed in an almost constant line of cliffs from Greene County, Pennsylvania, clear across West Virginia to the Big Kanawha River at Winfield.

This stratum is the only one in the series that is generally conglomeratic or contains quartz pebbles larger than coarse sand grains. On account of this peculiarity the rock in question becomes a very important guide to the geologist in the interior of West Virginia, where so many of the Dunkard Creek coals and limestones have disappeared, for it retains its pebbly character over a very wide area. When at its greatest development the thickness of this stratum approaches 75 and even 100 feet. It is usually a grayish white rock, with a yellowish cast on freshly broken surfaces, and its weathered bowlders are usually covered with ridges and streaks of harder iron-bearing sand. The rock splits readily and frequently furnishes excellent building stone, the piers of the Baltimore and Ohio Railroad bridges across the Monongahela River near Fairmont having been constructed of it.

Along the western border of the outcrop of this rock it dwindles down and changes its character entirely, being frequently represented in Washington County, Pennsylvania; Marshall and Ohio Counties, West Virginia; Belmont and Monroe Counties, of Ohio, by sandy shales and flaggy sandstones, and occasionally even a stratum of limestone may be found at this horizon.

In passing down the Ohio River below Marshall County the horizon of this sandstone passes below water level, but when it reappears near Saint Mary's, in P leasants County, the rock has regained its massiveness, and is a coarse pebbly sandstone 50 feet thick, and from this point on down the Ohio River, whenever above the level of the same, it is always a massive sandstone. From Blennerhasset Island, below Parkersburg, this rock is almost constantly visible either in the bed or bluffs of the Ohio on down to 25 miles below the mouth of the Great Kanawha. It is the emergence of this stratum from the bed of the stream which makes Letart Falls in the Ohio River. It is this rock which forms the great cliffs in the top of the hills at Red Rock, in Put-

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nam County, on the Great Kanawha, and the same may be seen as a bed of pebbly sandstone at many points in Ritchie, one at the famous Grahamite mine being especially noteworthy, for it is the great sandrock through which the celebrated fissure extends at the base of the hills, and it is there 75 feet thick.

Through Ritchie, Gilmer, and Calhoun Counties a bed of brecciated limestone occurs at the base of this stratum and incorporated with it, which is quite persistent and seems to replace the usual underlying Waynesburg coal, which is there absent.

THE CASSVILLE PLANT SHALE.

The Waynesburg sandstone often rests directly on the underlying Waynesburg coal, but more frequently a bed of dark gray shale, 5 to 15 feet thick, intervenes. This shale is always prolific in fossil plants and is especially so in the vicinity of Cassville, Monongalia County, West Virginia. It is from this locality and horizon that so many of the fossil plants were obtained which are described in the Second Geological Survey, Pennsylvania, Report PP, by Fontaine and White, and it is from the same shale that so many plants of Permian and even Triassic types have been procured, Tæniopteris, Saportæa, Baiera, and Pachypteris being among the number. No systematic search has ever been made at any other locality, and hence it is entirely probable that the list of fossil plants could be largely increased were this bed thoroughly explored in other regions. Other promising localities of the Cassville shale which have been slightly explored are Carmichael's, Greene County, Pennsylvania; Georgetown, Monongalia County; and West Union, Doddridge County. In connection with these roof shales, and sometimes interstratified with the top members of the underlying coal, there occur at Cassville numerous remains of insects, the principal ones being fossil cockroaches, of which Gerablattina seems to be the principal genus.

THE AGE OF THE DUNKARD CREEK BEDS.

The fauna of these rocks has never been systematically studied and its relationships determined. What desultory work has been done in this line goes to show that the animal forms consist principally of minute shells of crustaceans, fish remains, and insects, many of which are probably undescribed. No Brachiopods have ever been seen in these rocks, and hence one important line of evidence which might help to determine their relative age is wanting. Some geologists have been inclined to regard them as belonging in the Carboniferous proper because of the absence of the Permian reptilian fauna, and other types common elsewhere, but as the deposits are mainly of fresh water origin, the absence of such types is to be expected. Hence until the minute fauna occurring in these limestones and black slates shall have been carefully studied, the geologist must rely on the evidence of fossil plants.

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These have been studied by Prof. Wm. M. Fontaine and the writer, the results being published in Report PP, Second Geological Survey, Pennsylvania. The conclusions there given show that the flora is closely and unmistakably allied to the Permian of Europe, since it contains so many types that are peculiar to those rocks or even related to Mesozoic forms. The facts and conclusions set forth are sufficient to convince Prof. Archibald Geikie that these rocks are of the same age as the reptiliferous beds at Autun.

The conclusion that these rocks are of Permian age has not been accepted by all American geologists, though none have given any reasons for discrediting the evidence of the fossil plants on which it is based, and until it is contradicted by the animal remains or otherwise shown to be erroneous, no other hypothesis is tenable in view of the evidence at hand. The list of plants from which the Permian age of these Dunkard beds is inferred, together with the general discussion of the same, is given in Chapter III, pages 105, 120, Report PP, Second Geological Survey, Pennsylvania.

The recent discovery of an undoubted Permian invertebrate fauna in Texas by Prof. C. A. White and Mr. Cummins (American Naturalist, February, 1889), confirms the conclusions of Profs. Cope and Marcou with reference to the existence of a great Permian series of rocks in this country, and hence there is no longer any reason for doubting that America contains deposits which are equivalent in part at least to the Permian of Europe. The Texas deposits, as described by Prof. White in the article referred to, are so exactly similar lithologically to these uppermost beds of the Appalachian region, that the description of the one might well answer for that of the other, and there can be very little doubt that the two series are equivalent. Singularly enough the beds have practically the same thickness, 1,000 feet in Texas, and 1,100 in West Virginia and southwest Pennsylvania.

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CHAPTER III.

THE UPPER COAL MEASURES, OR MONONGAHELA RIVER SERIES.

THICKNESS, CHARACTER, AND EXTENT.

This series of rocks begins at base with the Pittsburgh coal and extends up to the Cassville shale. The thickness varies between 200 feet along the northwestern outcrop in Ohio and 380 feet in the Monongahela River region, but in the center of the Appalachian trough a boring at Browntown, Harrison County, West Virginia, carefully measured with steel line, reveals a thickness of 413 feet from the top of the Waynesburg coal to the bottom of the Pittsburgh bed.

Within the interval there belong six distinct coal beds, though only four of these are workable over any considerable area. These coals have their greatest development along the waters of the Monongahela River, and hence the series was long ago named after that river by Prof. H. D. Rogers.

The character of the rocks interstratified with the coal beds changes greatly in passing from the Monongahela River southward to the Great Kanawha. At the northern end of the basin in Marion, Monongalia, Greene, Washington, Fayette, and Westmoreland Counties, limestone forms about one-half of the rock material, and the same is true on the western side in Brooke, Ohio, Marshall, and Belmont Counties. Red shale is unknown in the series at the north, but in passing southward from Harrison and Lewis Counties the limestones practically disappear, and with them all of the coals except the Pittsburgh. With their disappearance red shales come in and apparently replace the limestones, so that on the Great Kanawha nearly one-fourth of the rock material in this series is red shale, while the thickness is reduced to 270 feet. Along with this change in the character of the rocks there occurs a great change in the topography made by these beds, for at the north, where limestone is abundant, sandstones are few and shaly, so that a gentle, rolling topography results, with a very rich soil and one of the finest grazing and farming regions in the country, while to the southwest, after the limestones have disappeared the sandstones thicken up and become more massive, thus giving rugged and precipitous slopes with narrow valleys.

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The character of the Upper Coal Measure rocks in the several portions of the area they occupy is shown by the several sections which follow.

Section in Fayette and Westmoreland Counties, Pennsylvania.—Prof. Stevenson, who has done so much to elaborate the detailed structure of this series, gives the following (Fig. 11), in Second Geological Survey, Pennsylvania, Report KK, page 31, as the general section of these beds in Fayette and Westmoreland Counties:

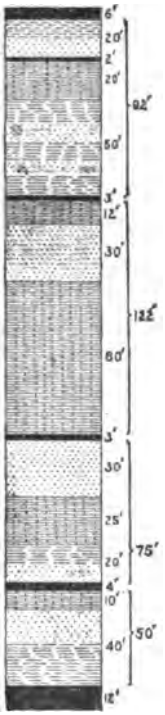

FIG. 11.—Section in Fayette and Westmoreland Counties, Pa.

Fayette and Westmoreland Counties, Pennsylvania.

[See map, K n.]

	Ft.	Ft.
1. Coal, Waynesburg		6
2. Sandy shales or sandstone	20	
3. Coal, Little Waynesburg	2	92
4. Limestone, Waynesburg	20	
5. Shale and shaly sandstone	50	
6. Coal, Uniontown		3
7. Limestone, Uniontown	12	
8. Sandstone	30	122
9. Limestone, "Great"	80	
10. Coal, Sewickley		3
11 Sandstone	30	
12. Limestone, Sewickley	25	75
13. Shale or shaly sandstone	20	
14. Coal, Redstone		4
15. Limestone, Redstone	10	
16. Sandstone or shale	40	50
17. Coal, Pittsburgh		12
Total		367

Section at Brownsville, Pennsylvania.—At Brownsville, Fayette County, Pennsylvania, Prof. Stevenson finds the following structure, (Fig. 12), for this series, as given in KK, page 233:

Brownsville, Fayette County, Pennsylvania.

[See map, K m.]

	Ft. in.	Ft. in.
1. Coal, Waynesburg, blossom		
2. Shales, sandy	45	
3. Coal, Little Waynesburg, blossom	0	104
4. Limestone, Waynesburg	4	
5. Shales and shaly sandstone	55	
6. Coal, Uniontown, blossom		
7. Limestone, coarse, yellow	1	
8. Clay	3	
9. Shale and sandstone	16	
10. Limestone	2	
11. Concealed	17	121
12. Sandstone	3	
13. Limestone with shales	42	
14. Concealed	16	
15. Limestone	6	
16. Concealed	7	
17. Clay shale	8	
18. Sewickley coal horizon		
19. Sandy shale and flaggy sandstone	30	
20. Limestone	30	95
21. Shale	35	
22. Coal, Redstone		0 6
23. Shale, sandy		25
24. Coal, Pittsburgh { Coal....0' 8", Clay....0' 10", Coal .. 7' 6" }		9
Total		354 6

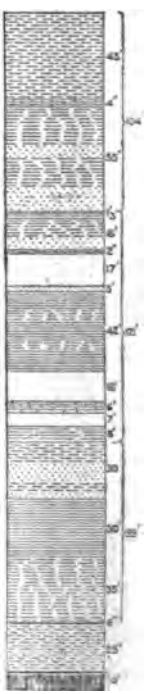

FIG. 12.—Section at Brownsville, Pa.

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UPPER COAL MEASURES CAPPED WITH PERMO-CARBONIFEROUS BEDS, WHEELING, WEST VIRGINIA.

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Section at West Brownsville, Pennsylvania.—On the opposite side of the Monongahela River, in descending from Kreb's Knob to West Brownsville, in Washington County, the writer measured the several members of this series with the following results (Fig. 13):

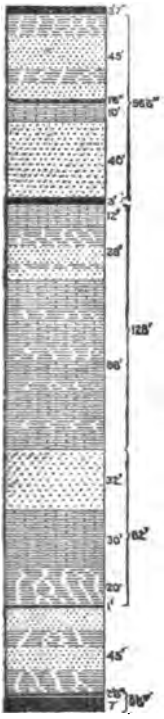

FIG. 13.—Section at West Brownsville, Pa.

West Brownsville, Washington County, Pennsylvania.

[See map, K m.]

		Ft. in.	Ft. in.
1, Coal, Waynesburg	Coal.....0′ 10″; Clay.....0′ 3″; Coal.....2′ 6″		3 7
2. Shales and sandstone		45	
3. Bitumenous shale, Little Waynesburg Coal		1 6	
4. Limestone, Waynesburg		10	96 6
5. Sandstone, shaly		40	
6. Coal, Uniontown			3
7. Limestone, Uniontown		12	
8. Shale and sandstone		28	128
9. Limestone, with thin shales		88	
10. Coal, Sewickley, blossom			
11. Sandstone, shaly		32	
12. Limestone		30	82
13. Shales		20	
14. Coal, Redstone			1
15. Sandstone and shales			45
16. Coal, Pittsburgh, roof	Coal..0′ 3″; Clay..0′ 3″; Coal..1′ 0″; Clay..1′ 0″	2 6	9 6
17. Coal, Pittsburgh, main bench		7 0	
Total			368 7

Section at Rice's Landing, Pennsylvania.—In the steep hillside, one mile below Rice's Landing, Greene County, Pennsylvania, the series exhibits the following structure (Fig. 14):

Rice's Landing, Greene County, Pennsylvania.

[See map, K m.]

		Ft. in.	Ft. in.
1. Waynesburg coal	Coal....1′ 0″; Clay....0′ 5″; Coal....1′ 3″; Clay....1′ 2″; Coal....2′ 6″		6 4
2. Shales		40	
3. Limestone, Waynesburg		6	91
4. Shales and sandstone		45	
5. Coal, Uniontown			1 6
6. Limestone, Uniontown		6	
7. Shales and sandstone		38	126
8. Limestone, "Great"		82	
9. Coal, Sewickley			1 9
10. Sandstone		40	
11. Limestone		25	95
12. Sandy shale		30	
13. Slate, bituminous (Redstone coal)			1 6
14. Sandstone, Pittsburgh, flaggy		15	
15. Sandstone, Pittsburgh, massive		30	45
16. Coal, Pittsburgh	Roof. Coaly shale..1′ 0″; Coal.....1′ 2″; Clay.....0′ 10″; Main bench .....7′ 0″		10
Total			378 1

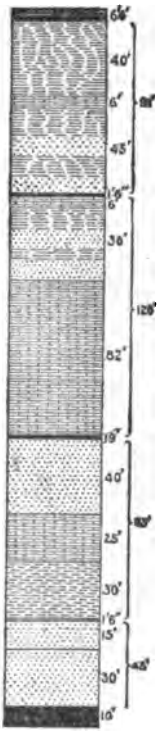

FIG. 14.—Section at Rice's Landing, Pa.

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Section on Robinson's Run, West Virginia.—The Upper Coal Measure beds attain a very fine development in Monongalia County, West Virginia, just south from the Greene County line, and there, on Robinson's Run, 2 miles west from the Monongahela River, the following succession (Fig. 15) is exposed:

Robinson's Run, Monongalia County, West Virginia.

[See map, L m.]

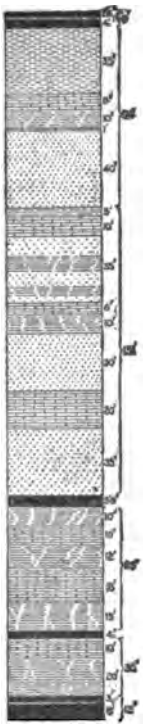

FIG. 15.—Section on Robinson's Run, W. Va.

		Ft. in.	Ft. in.
1.	Coal, Waynesburg .. { Coal...2′ 6″; Shale..1′ 6″; Coal ..4′ 0″ }		8
2.	Sandy shales with iron ore below middle	35	
3.	Limestone, Waynesburg	8	
4.	Shales	10	94
5.	Limestone	1	
6.	Sandstone, flaggy	40	
7.	Black slate (Uniontown coal)	5	
8.	Limestone, Uniontown	10	
9.	Sandstone and shales	35	
10.	Limestone	6	151
11.	Shales	10	
12.	Sandstone, flaggy	30	
13.	Limestone, cement beds	20	
14.	Sandstone, Sewickley	35	
15.	Coal, Sewickley		5 6
16.	Shales	10	
17.	Limestone	10	
18.	Shales	12	65
19.	Limestone	18	
20.	Shales	15	
21.	Coal, Redstone		4
22.	Limestone, Redstone	10	30
23.	Shales and slates	20	
24.	Coal, Pittsburgh.... { Roof coals..3′; Clay.....1′; Coal.....8′ }		12
	Total		369 6

Here, as will be seen from the above section, the Redstone coal, which belongs between the Pittsburgh and Sewickley beds, has thickened up into merchantable condition. This coal contains a little more sulphur than either the Pittsburgh below or the Sewickley above, but it makes a very fair fuel for domestic and steam-producing purposes. It is softer than either of the other two and would coke well.

The Redstone, Pittsburgh, and Sewickley beds of this section foot up a total thickness of 21½ feet, including partings, and about 17 feet of this is merchantable coal.

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Section on Scott's Run, West Virginia.—A short distance south from Robinson's Run, we get another fine exposure of the Upper Coal Measure beds along the waters of Scott's Run, between Cassville and the mouth of the stream, as follows (Fig. 16):

Scott's Run, Monongalia County, West Virginia.

[See map, M m.]

		Ft.	in.	Ft.	in.
1. Coal, Waynesburg	Coal 2′ 0″; Shale, fossiliferous 1′ 0″; Coal 1′ 4″; Shale, gray 1′ 6″; Coal 5′ 0″			10	10
2. Black slate		1			
3. Sandy shales, with iron ore		25			
4. Limestone, Waynesburg		8		99	
5. Sandy shales, with limestone layers		30			
6. Sandstone, massive		20			
7. Limestone and shales		15			
8. Black slate, representing Uniontown coal				2	
9. Limestones, interstratified with thin shales, cement beds near base		105		145	
10. Sandstone, Sewickley		40			
11. Coal, Sewickley				5	
12. Shales		5			
13. Sandstone		10			
14. Limestone		5			
15. Shales, greenish gray		8		65	
16. Concealed		15			
17. Limestone, steel gray		7			
18. Concealed		15			
19. Coal, Redstone				4	
20. Limestone, Redstone		18			
21. Shale and fire clay		5		28	
22. Slate, black		5			
23. Coal, Pittsburgh, roof	Coal 0′ 3″; Shale 2′ 0″; Coal 1′ 0″; Clay 1′ 0″	4	3		
24. Coal, Pittsburgh, main bench	Coal 3′ 6″; Slate 0′ ½″; Coal 0′ 8″; Slate 0′ 1″; Coal 1′ 6″; Slate 0′ ½″; Coal 0′ 6″; Slate 0′ ½″; Coal 3′ 3″	9	7½	13	10½
Total				372	8½

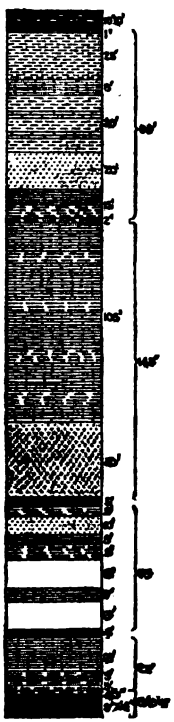

FIG. 16.—Section on Scott's Run, W. Va.

The same Redstone coal makes its appearance in this section; in fact it underlies all of the region intervening between Scott's and Robinson's Runs, thinning out southward as well as northward. It underlies an area of probably 5,000 acres where it is of workable thickness. In the oil-well borings on Doll's Run, and as far west as Mannington and Fairview, this bed is still present, though apparently not of workable thickness.

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Section on Buffalo Creek, West Virginia.—Along Buffalo Creek, in the vicinity of Fairmont, Marion County, West Virginia, the Upper Coal Measures exhibit the following succession (Fig. 17):

Buffalo Creek, Marion County, West Virginia.

[See map, M l.]

		Ft.	in.	Ft.	in.
1. Coal, Waynesburg	Coal...0′ 6″; Shale..0′ 1″; Coal..1′ 0″; Shale..1′ 4″; Coal...3′ 0″			5	11
2. Shales		20			
3. Sandstone, massive		30			
4. Shale		3			
5. Limestone, Waynesburg		1	6		
6. Shales		18		101	
7. Limestone		1	6		
8. Shales		12			
9. Sandstone		10			
10. Shales		5			
11. Coal, Uniontown				2	6
12. Fire clay		4			
13. Sandstone		1			
14. Shales and black slate		5			
15. Limestone		3			
16. Fire clay		5			
17. Shales with limestone		5			
18. Sandstone		2		149	
19. Blue shale		8			
20. Limestone		1			
21. Shales and concealed		25			
22. Limestone interstratified with thin shales		85			
23. Shales		5			
24. Coal, Sewickley	Coal.....5′ 0″; Clay.....0′ 4″; Coal.....0′ 4″; Slate, dark .0′ 3″; Coal.....0′ 5″			6	4
25. Shales		3	6		
26. Limestone, buff		4			
27. Sandstone, gray, massive		18			
28. Limestone, gray		5			
29. Concealed and shales		15		100	6
30. Impure clay		5			
31. Limestone and shales		20			
32. Sandstone, Pittsburgh		25			
33. Shales		5			
34. Coal, Pittsburgh	Coal, bony.0′ 10″; Bone.....0′ 1½″; Coal.....2′ 3″; Slate.....0′ ¼″; Coal.....0′ 5″; Slate.....0′ ¼″; Coal.....3′ 5½″			7	1½
Total				372	4½

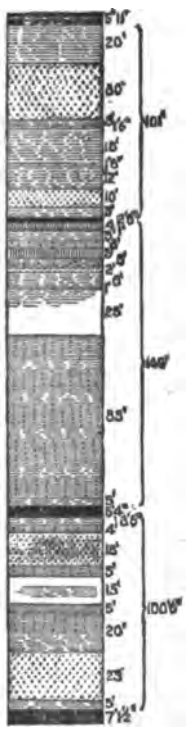

FIG. 17.—Section on Buffalo Creek, W. Va.

The portion of this section from the Sewickley coal down to the base of the series was measured at the Montana mines, 2½ miles below the mouth of Buffalo Creek.

The Redstone coal is entirely absent here, its horizon being occupied by the 5 feet of impure fire clay, 50 feet above the Pittsburgh bed.

Section at Clarksburg, West Virginia.—In passing from Marion County southward towards Clarksburg, in Harrison County, a great change takes place in the character of the sediments of the Upper Coal Meas-

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ures. The limestones, so prominent in Greene, Monongalia, and Marion, dwindle down to insignificant proportions, as shown by the following section (Fig. 18), made at Clarksburg by Mr. Jno. L. Johnston, civil engineer:

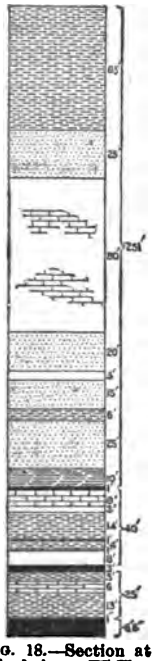

FIG. 18.—Section at Clarksburg, W. Va.

Clarksburg, Harrison County, West Virginia.

[See map, O k.]

		Ft.	in.	Ft.	in.
1.	Waynesburg coal, absent or not seen			0	
2.	Concealed and yellow sandy shales	65			
3.	Sandstone	25			
4.	Concealed, with some limestone	80			
5.	Sandstone	20			
6.	Concealed	5		251	
7.	Sandstone	15			
8.	Sandy shales	6			
9.	Sandstone, Sewickley	25			
10.	Shales	10			
11.	Coal, Sewickley			1	
12.	Limestone { Shaly ....1′ 6″ / Good ....7′ 6″ }	9			
13.	Concealed	3			
14.	Shales, sandy	14			
15.	Shale, with iron nodules	1		40	
16.	Shales, sandy	4			
17.	Sandstone	1			
18.	Concealed	8			
19.	Coal, Redstone, slaty			3	
20.	Shale, dark, bituminous	5			
21.	Limestone, Redstone	6			
22.	Shale, greenish	13		25	
23.	Slate, bituminous	1			
24.	Coal, Pittsburgh { Coal....3′ 5″ / Bone ...0′ 1″ / Coal....5′ 0″ }			8	6
	Total			328	6

Section at Chapline Hill, Wheeling, West Virginia.—Between the Monongahela and Ohio Rivers a considerable change takes place in the character of the Upper Coal Measure beds, and also in the thickness of the several members, as will be seen by the following section (Fig. 19) from Chapline Hill, Wheeling, West Virginia:

Chapline Hill, Wheeling, West Virginia.

[See map, K j.]

		Ft.	in.	Ft.	in.
1.	Coal, Waynesburg			2	
2.	Concealed	5			
3.	Flaggy sandstone, filled with plant fragments	4			
4.	Concealed	4			
5.	Limestone, shales and concealed	60			
6.	Sandstone, massive, gray	5		158	
7.	Limestone and concealed	20			
8.	Green shale	5			
9.	Limestone, interstratified with shales	55			
10.	Coal, Sewickley { Coal / Sandy shales with plants / Coal }	1 / 12 / 0	0 / 0 / 8	13	8
11.	Shales	8			
12.	Sandstone, rather massive, micaceous, current-bedded	20		29	
13.	Limestone, impure, flaggy, filled with fossil ferns	1			
14.	Coal, Redstone			0	10
15.	Limestone, mostly buffish and impure			55	
16.	Pittsburgh coal { Coal, roof....2′ / Shale....2′ / Coal, main bench..5′ }			9	
	Total			267	6

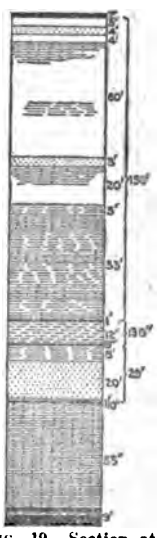

FIG. 19.—Section at Chapline Hill, Wheeling, W. Va.

Here the Waynesburg coal has dwindled to an unimportant bed, and the Sewickley has split into two portions separated by 12 feet of shales, while the whole column has lost more than 100 feet of thickness compared with the Monongahela River region.

Section near Bellaire, Ohio.—At Bellaire, Ohio, 4 miles below Wheeling, the following carefully leveled section (Fig. 20) was made by Prof. C. N. Brown, of the present Ohio Geological Survey. It exhibits some interesting changes as compared with the Wheeling section:

Near Bellaire, Belmont County, Ohio.

[See map, K 1.]

	Ft.	in.	Ft.	in.
1. Coal, Waynesburg			2	
2. Shale, sandy	6			
3. Shale	12			
4. Limestone	3		40	
5. Concealed	5			
6. Coal, blossom, Little Waynesburg				
7. Concealed	14			
8. Coal, blossom, Uniontown			1	
9. Shale	4			
10. Sandstone	6			
11. Shale, argillaceous	20			
12. Concealed	32			
13. Shale	2		127	6
14. Sandstone	3			
15. Shale	3			
16. Concealed	33			
17. Calcareous shale, with thin limestones	24	6		
18. Coal, Sewickley: Coal 4′ 0″; Shales, sandy 13′ 10″; Coal 0′ 8″; Shale, argillaceous 6′ 0″; Coal 3′ 0″			27	6
19. Shale, argillaceous	2			
20. Limestone, thin clay in center	8			
21. Limestone, magnesian, cement rock	5		38	
22. Clay	1			
23. Limestone	11			
24. Concealed	11			
25. Coal, Redstone, blossom			2	
26. Concealed	17		18	
27. Shale	1			
28. Coal, Pittsburgh			7	
Total			263	

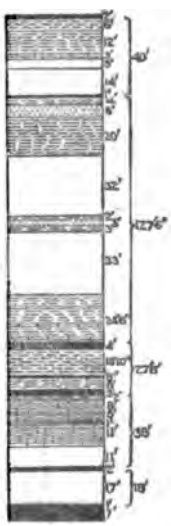

FIG. 20.—Section near Bellaire, Ohio.

The interval between the two members of the Sewickley coal has here increased to 20 feet, and the upper one seems to keep permanently above the lower one from here southwestward through Ohio, becoming the Cumberland and Meigs Creek bed of the Ohio geologists.

Both the Little Waynesburg and Uniontown coals are represented in this section, but neither one was observed at Wheeling.

It is worthy of note that there is a difference of only 4 feet in the total thickness of the Upper Coal Measures as given by Prof. Brown's section at Bellaire and mine at Wheeling, four miles above.

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UPPER COAL MEASURES AND PERMO-CARBONIFEROUS, POWHATAN, OHIO.

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Section at Moundsville, West Virginia.—Near the mouth of Grave Creek, one mile below Moundsville, West Virginia, and 7 miles below Bellaire, these measures exhibit the following succession by combining the surface exposures with the record of an oil boring (Fig. 21):

Moundsville, Marshall County, West Virginia.

[See map, K 1.]

		Ft. in.	Ft. in.
1. Coal, Waynesburg	Coal, impure 0′ 6″; Shale 1′ 0″; Coal 1′ 6″		3
2. Shale, soft, gray		5	
3. Sandstone, massive, gray, micaceous		20	
4. Concealed, with limestone layers at base 2 feet thick		20	
5. Flaggy sandstone and sandy shales		20	
6. Concealed		10	
7. Limestone		1	
8. Concealed		14	223
9. Limestone, gray		22	
10. Concealed to mouth of oil and gas well at 30 feet above low-water mark in Ohio River		28	
11. Conductor hole of oil-well record		18	
12. Limestone, light gray		40	
13. Slate		15	
14. Black rock, shales		10	
15. Coal, Redstone			1 6
16. Fire clay		7	
17. Hard slate		4	41
18. Gray limestone		20	
19. Bastard limestone		10	
20. Coal, Pittsburgh			6
Total			274 6

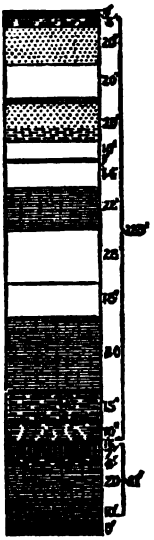

FIG. 21.—Section at Moundsville, W. Va.

Section on Pipe Creek, Ohio.—Pipe Creek puts into the Ohio River 3 miles below the mouth of Grave Creek, and there, on the Belmont County side of the river, the Pittsburgh coal is at low-water level. The following structure (Fig. 22) is found in the steep hills which border the mouth of Pipe Creek:

Pipe Creek, Belmont County, Ohio.

[See map, K 1.]

		Feet.	Feet.
1. Coal, Waynesburg, slaty at top			4
2. Concealed, limestone and shales			55
3. Bituminous slate, Uniontown coal			1
4. Limestone, Uniontown		10	110
5. Concealed, with much limestone		100	
6. Coal, Sewickley	Coal, and coaly shale 2′ 0″; Sandstone 12′ 0″; Coal 0′ 4″; Shale 1′ 0″; Coal 0′ 4″; Shale, sandy 5′ 0″; Coal, slaty 1′ 8″; Shale 0′ 4″; Coal 1′ 0″; Black slate 0′ 4″		24
7. Limestone, Sewickley, and shales			22
8. Bituminous shale, (Redstone coal)			1
9. Limestone, (Redstone) and concealed			25
10. Coal, Pittsburgh			6
Total			248

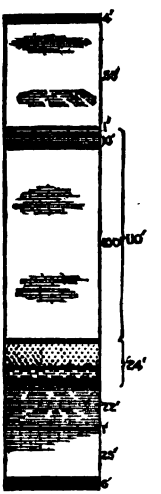

FIG. 22.—Section in Belmont County, Ohio.

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Below this last locality no measurement of the Upper Coal Measure series is possible for a long distance, because most of the members are below water level. They are all brought to the surface, however, by the Volcano anticline, which crosses the Ohio River from Pleasants County, West Virginia, into Washington County, Ohio.

Section in Washington County, Ohio.—Mr. F. W. Minshall, of Marietta, Ohio, has made a very careful study of these measures in Washington County, Ohio, and has prepared the following section (Fig. 23) as representing their usual structure there:

Washington County, Ohio.

[See map, M g.]	Ft. in.	Ft. in.
1. Coal, Waynesburg (Macksburg)		4
2. Shale	14	
3. Sandstone	11	
4. Shale	18	
5. Limestone	6	96
6. Shaly sandstone	18	
7. Limestone and shale	29	
8. Coal, Sewickley (Meigs Creek)		2 6
9. Shales and limestone	25	
10. Shales	40	88
11. Sandstone	19	
12. Shales	4	
13. Coal, Pittsburgh, thin		
Total		190 6

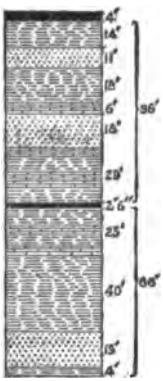

FIG. 23.—Section in Washington County, Ohio.

The thickness here given is 50 to 60 feet less for the entire series than that usually found in any other portion of the Appalachian field.

Section at Burning Springs, West Virginia.—In the vicinity of Burning Springs, Wirt County, West Virginia, these rocks are brought above the surface by the same anticline, and there Mr. Minshall reports the following structure (Fig. 24):

Burning Springs, Wirt County, West Virginia.

[See map, P g.]	Ft. in.
1. Coal, Waynesburg	1 8
2. Concealed and shales	207
3. Sandstone, Pittsburgh	30
4. Shales	10
5. Coal, Pittsburgh	1 8
Total	250 4

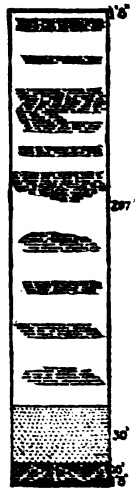

FIG. 24.—Section at Burning Springs, W. Va.

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Both here and all along the Volcano anticline the Pittsburgh coal is very poorly developed, as shown in this and the previous section, and it is frequently absent entirely.

Section on Leading Creek, West Virginia.—Near Leading Creek post-office, at the eastern edge of Gilmer County, West Virginia, this series shows thus (Fig. 25):

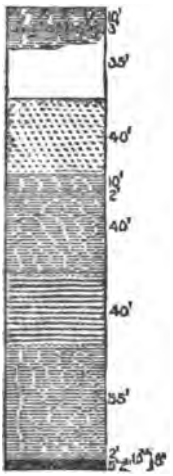

FIG. 25.—Section on Leading Creek, W. Va.

Leading Creek, Gilmer County, West Virginia.

[See map, P j.]

		Feet.
1.	Waynesburg coal horizon (absent)	0
2.	Shales	10
3.	Limestone, brecciated	3
4.	Shales and concealed	35
5.	Sandstone, yellow, massive, soft, pebbly	40
6.	Shales	10
7.	Limestone, impure	2
8.	Shales	40
9.	Sandstone, massive	40
10.	Shales	55
11.	Coal, Pittsburgh: Coaly shales 2′ 0″; Clay 0′ 10″; Bony coal 0′ 6″; Coal 2′ 4″; Bony slate 0′ 4″; Coal 2′ 0″	8
	Total	243

Section at Antiquity, Ohio.—Along the Ohio River, below where the Volcano arch crosses, the Upper Coal Measures again plunge under water level, and do not emerge again till we come to the vicinity of Antiquity, Meigs County, Ohio, 100 miles below. A shaft to the Pittsburgh bed (130 feet under river level), taken in connection with the surface exposures there, reveals the following succession (Fig. 26):

Antiquity, Meigs County, Ohio.

[See map, P e.]

		Ft.	in.
1.	Waynesburg coal (absent)	0	
2.	Shales and sandstones	172	
3.	Sandstone, massive, Pittsburgh	70	
4.	Shales, with fossil plants	10	
5.	Coal, Pittsburgh: Coal 2′ 6″; Slate 0′ 2″; Coal 3′ 0″	5	8
	Total	257	8

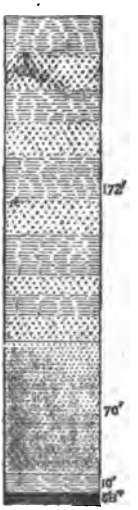

FIG. 26.—Section at Antiquity, Ohio.

Section at Hartford City, West Virginia.—Six miles below the shaft at Antiquity, and in the vicinity of Hartford City, the Pittsburgh coal

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comes above water level. In the steep bluffs above Hartford the following succession (Fig. 27) was observed:

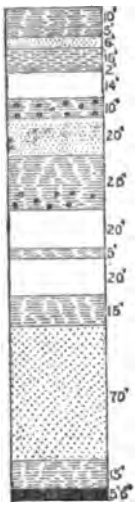

FIG. 27.—Section at Hartford City, W. Va.

Hartford City, Mason County, West Virginia.

[See map, P d.]

	Ft.	in.
1. Waynesburg coal (absent)	0	
2. Red shale	10	
3. Shale, gray	5	
4. Sandstone	6	
5. Shales, brown, sandy	10	
6. Shales, red	2	
7. Concealed	14	
8. Red shale, with limestone nodules	10	
9. Sandstone	20	
10. Shales, variegated with limestone nodules near base	28	
11. Concealed	20	
12. Red shale	5	
13. Concealed	20	
14. Shale, red	15	
15. Sandstone, massive, Pittsburgh	70	
16. Shales, gray, fossil plants	15	
17. Coal, Pittsburgh	5	6
Total	255	6

Section at Arbuckle, West Virginia.—In the vicinity of Arbuckle, Mason County, West Virginia, on the Great Kanawha River, and 18 miles above its mouth, the Waynesburg coal makes its appearance in the section. Here the following structure (Fig. 28) was obtained for the series, by combining the surface exposures with the record of a boring made by Mr. Craig:

Arbuckle, Mason County, West Virginia.

[See map, Q e.]

		Ft.
1. Waynesburg coal	Coal, slaty 0′ 10″; Coal, sulphurous 0′ 8″; Shale, dark 0′ 5″; Coal, good 0′ 8″; Coal, slaty 0′ 5″	3
2. Shales, sandstone, and concealed		150
3. Sandstone, blue		4
4. Shales, red		2
5. Sandstone, blue, hard		14
6. Variegated shales		8
7. Coal, Sewickley		1
8. Sandstone		6
9. Shales, red		4
10. Shales, variegated		48
11. Fire clay, impure (Redstone coal)		2
12. Sandstone, coarse, white, Pittsburgh		29
13. Fire clay and shale with a little slaty coal at bottom, Pittsburgh		10
Total		281

FIG. 28.—Section at Arbuckle, W. Va.

Here there is practically no merchantable coal in the whole series, since the Waynesburg bed, although 3 feet thick, is poor and slaty.

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The locality is near the center of the deepest portion of the Appalachian trough, and the horizon of the Pittsburgh coal is 90 feet under the Kanawha. A hole was drilled as a test for this coal, but the result proved only a trace of it present.

Section at mouth of Big Hurricane Creek, Putnam County, West Virginia.—Southward up the Kanawha River from Arbuckle, the locality of Section 28, the rocks rise and the entire series comes above water level at the mouth of Big Hurricane Creek, in Putnam County. Here, 32 miles from the mouth of the Big Kanawha, the following succession may be seen (Fig. 29):

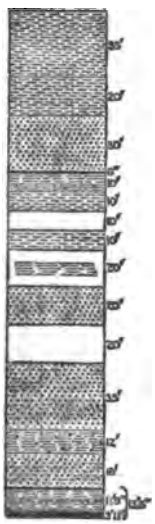

FIG. 29.—Section at mouth of Big Hurricane Creek, W. Va.

Mouth of Big Hurricane Creek, Putnam County, West Virginia.

[See map, R d.]

				Ft.	in.
1. Waynesburg coal (absent)				0	
2. Shales, red and sandy				35	
3. Sandy shales				20	
4. Sandstone, massive				30	
5. Coal, Uniontown				0	6
6. Red shales, with limestone				10	
7. Shales, sandy				10	
8. Concealed				10	
9. Shales, sandy				10	
10. Concealed and red shales				20	
11. Sandstone, massive				20	
12. Concealed				20	
13. Sandstone, massive				35	
14. Shale, with iron ore				12	
15. Sandstone				18	
16. Coal, Pittsburgh, roof	Coal	0′ 10″	11′ 9″	15	8
	Shales	5′ 0″			
	Slate, black	1′ 0″			
	Sandstone	1′ 8″			
	Slate, black	2′ 0″			
	Fire clay	1′ 3″			
17. Coal, Pittsburgh, main bench	Coal	3′ 3″	3′ 11″		
	Slate	0′ 2″			
	Coal	0′ 6″			
Total				266	2

The Pittsburgh coal is patchy all through this region, being workable on some farms and absent on others.

Section opposite Winfield, West Virginia.—As showing the unreliable character of the coals in this series along this portion of the Kanawha, the section (Fig. 30) of the rocks opposite Winfield, Putnam County, 5 miles above Big Hurricane, is given:

Opposite Winfield, Putnam County, West Virginia.

[See map, S e.]

	Ft.
1. Waynesburg coal (absent)	0
2. Shales, red, with limestone nodules	5
3. Sandstone, shaly	10
4. Concealed	10
5. Red shale	10
6. Sandstone, flaggy	30
7. Red shales, with limestone	10
8. Sandstone, shaly	20
9. Red shale	25
10. Sandstone, shaly	10
11. Red shales	10
12. Sandstone, flaggy	10
13. Concealed	10
14. Red shale, with limestone nodules near base	15
15. Sandstones, red, and gray shales	75
16. Fire clay, place for Pittsburgh coal	0
Total	250

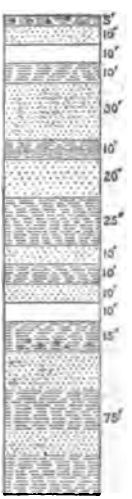

FIG. 30.—Section opposite Winfield, W. Va.

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This section was measured in the steep hill at Red House Station, on the Kanawha and Ohio Railroad, and, as may be seen, the series does not there contain any coal whatever.

Section near Raymond City, West Virginia.—Further up the Kanawha the Pittsburgh coal again comes in, and the following structure (Fig. 31) is found in the vicinity of Raymond City, 6 miles above Winfield:

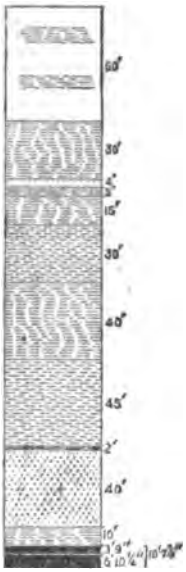

FIG. 31.—Section near Raymond City, W. Va.

Near Raymond City, Putnam County, West Virginia.

[See map, S e.]

			Ft.	in.
1. Waynesburg coal (absent)			0	
2. Concealed, with red shale			60	
3. Red shale			30	
4. Sandstone, gray, micaceous			4	
5. Limestone, in red shale			5	
6. Red shale			15	
7. Sandy shale, gray			30	
8. Shale, red			40	
9. Sandy shales, yellowish gray			45	
10. Black shale, Redstone coal			2	
11. Sandstone, Pittsburgh			40	
12. Shales			10	
13. Coal, Pittsburgh, roof	Coal	0′ 4″	10	7½
	Shale	0′ 4″		
	Coal	0′ 6″		
	Shale	0′ 1″		
	Coal, slaty	1′ 0″		
	Fine clay	1′ 6″		
		3′ 9″		
14. Coal, Pittsburgh, main bench	Coal, good	6′ 0″		
	Slate	0′ ½″		
	Coal, slaty	0′ 10″		
		6′ 10½″		
Total			291	7½

Section in vicinity of Western Port, Maryland.—In the Cumberland or Georges Creek basin, the Upper Coal Measures exhibit the following structure (Fig. 32), as observed in the vicinity of Western Port, Maryland:

Vicinity of Western Port, Alleghany County, Maryland.

[See map, N p.]

				Ft.	in.
1. Waynesburg coal (not seen)				0	
2. Concealed and shales				130	
3. Coal, Sewickley				5	
4. Shales and concealed				115	
5. Coal, Pittsburgh, roof	Coal	0′ 8″		20	3¼
	Shale	4′ 0″			
	Coal	1′ 0″			
	Shale	1′ 0″			
			6′ 8″		
6. Coal, Pittsburgh, main bench	Coal	10′ 0″			
	Slate	0′ 2″			
	Coal	0′ 9″			
	Slate	0′ ½″			
	Coal	2′ 0″			
	Black slate	0′ 6″			
	Soft coaly shale	0′ 2″			
			13′ 7½″		
Total				270	3¼

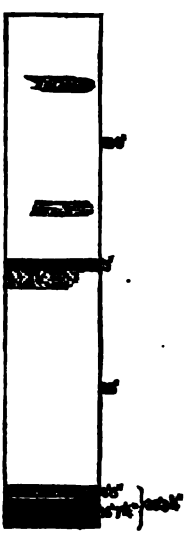

FIG. 32.—Section near Western Port, Md.

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From the foregoing sections it will be perceived that the beds in the Upper Coal Measures which have received distinct names are in descending order as follows:

Waynesburg coal.	Sewickley sandstone.
Browntown sandstone.	Sewickley coal.
Little Waynesburg coal.	Sewickley limestone.
Waynesburg limestone.	Redstone coal.
Uniontown sandstone.	Redstone limestone.
Uniontown coal.	Pittsburgh sandstone.
Uniontown limestone.	Pittsburgh coal.
Great limestone.	

These several beds we shall now notice more in detail.

CHARACTERISTIC HORIZONS.

THE WAYNESBURG COAL.

This, the highest member of the series, is generally quite persistent around the northern end of the coal field, but followed southward through West Virginia it soon becomes patchy and interrupted, so that beyond the line of Marion County the coal is only occasionally present along the eastern and central portions of the Upper Coal Measure belt, its horizon being frequently occupied, as at Harrisville, Ritchie County, by a brecciated limestone.

On the Great Kanawha this coal occurs near the center of the Appalachian trough over a small area in the vicinity of Arbuckle, and its structure there is given in Section 28.

Along the western side of the field, down the Ohio River and across southern Ohio, this coal is fairly persistent. It dips under the Ohio River at New Martinsville, but rises to daylight again near St. Mary's, where it is only 1 to 3 feet thick, and quite sulphurous.

In the Macksburg oil region it is the principal bed, according to the Ohio geologists, and has a thickness of 4 feet.

This coal is almost universally double, being separated into two layers by a division of shale and slate. This is so common at the northern end of the field that it is known there as the "horse-back" vein. In Monongalia and Greene Counties the bed is often 8 to 10 feet thick and separated into three layers, the upper division of slate being very fossiliferous, and often, as at Cassville, West Virginia, containing many insect remains, together with fossil plants.

The coal from this bed is usually rather hard, and comes out in large blocks; but it frequently contains injurious quantities of sulphur. This renders it unfit for smithing, as well as for the manufacture of coke and gas, but it is generally a useful fuel for steam and domestic purposes.

IRON ORE.

The shales which underlie the Waynesburg coal sometimes contain a considerable quantity of iron nodules, and they were once mined in

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Morgan Township, Greene County, Pennsylvania, and used in manufacturing iron. The same ore occurs near Bethel Church, Cass District, Monongalia County, at 15 to 20 feet below the coal.

THE BROWNTOWN SANDSTONE.

In many portions of Marion and Harrison Counties, West Virginia, the interval beginning 5 to 10 feet below the Waynesburg coal is occupied by a hard, gray, massive sandstone, 20 to 35 feet thick. It is finely exposed along the bed and bluffs of Ten Mile Creek, at and below Browntown, Harrison County, West Virginia, and has been designated from that locality. The deep, rocky cuts along the Baltimore and Ohio Railroad, beginning 1 mile east of Mannington, Marion County, and extending to the mouth of Mod's Run, are all in this sandstone. It is sometimes called the "Gilboy" sandstone, from a rocky cut of that name near Mannington. This is nearly always a water-bearing stratum, and the oil wells of Marion County have to be cased below this rock in order to shut off the fresh water.

THE LITTLE WAYNESBURG COAL.

At many localities around the northern end of the Upper Coal Measure area a thin streak of coal or bituminous slate occurs at 25 to 40 feet below the Waynesburg coal, and it was termed the Little Waynesburg coal by Prof. Stevenson. It seldom exceeds 1 foot in thickness, and is of no economic importance. It is usually separated from the main coal above by shales and sandy beds, and should probably be regarded as an offshoot from the Waynesburg coal proper. It is seldom seen south from the Pennsylvania line, though it occurs along the Ohio River at several places.

THE WAYNESBURG LIMESTONE.

Directly under the last described stratum there occurs a limestone of very wide distribution. Its place is generally about 40 feet below the Waynesburg coal, though sometimes it is less, and occasionally a few feet more. It is usually of a dark gray color, and several of the layers make excellent lime for agricultural and building purposes. The thickness in Pennsylvania and northern West Virginia is seldom less than 8 feet, and frequently double that, but southwestward, toward the Great Kanawha region, the limestone disappears entirely.

THE UNIONTOWN SANDSTONE.

At 60 to 75 feet below the top of the series there frequently occurs a massive, gray sandstone whose horizon comes immediately above the Uniontown coal; and hence, although the stratum in question is not prominent at Uniontown, it has been designated from its relations to the underlying coal.

The rock has occasionally been mistaken for the Waynesburg sandstone, which belongs nearly 100 feet above. It is well exposed at Bob-

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town, Greene County, Pennsylvania, where it crowns the summit of the hill overlooking Dunkard Creek as a bold cliff.

In the Georges Creek coal field a massive sandstone occurs 250 feet above the Pittsburgh coal, and it was once referred by the writer to the Uniontown horizon under the name of "Westernport sandstone," but subsequent study seems to place it in the horizon of the Waynesburg sandstone.

THE UNIONTOWN COAL.

This bed underlies the Waynesburg coal by an interval of 80 to 100 feet, and is of economic importance only in Fayette and Washington Counties, Pennsylvania. It was named by Rogers from Uniontown, Fayette County, where it is well exposed. The thickness seldom exceeds 3 feet, even in the region of its best development, and the coal has never been used except for domestic purposes, since it is usually neglected for the great Pittsburgh bed below. It often contains a clay or slate parting near the center, 4 to 6 inches thick, and is rather too rich in ash for a first-class fuel.

Southward from Fayette County, through Greene, Monongalia, Marion, and Harrison, this coal thins away to a bed of black slate mixed with slaty coal that is often rich in fish remains and bivalve crustaceans, which may be found in abundance near Davistown, Greene County, Pennsylvania.

Along the Ohio River at Wheeling, Bellaire, Clarington, and other points, this bed is sometimes represented by a thin streak of black slate or coal. In the Salisbury basin of Pennsylvania it is recognized by Messrs. Platt, and is there over 3 feet thick, with slate near center.

THE UNIONTOWN LIMESTONE.

To the division of the "Great" Limestone which immediately underlies the last described coal bed, Dr. Stevenson gave the name Uniontown, since it seems to be fairly well separated from the great mass of limy deposits below. This division is usually 10 to 15 feet thick, though occasionally it surpasses these figures. The rock is frequently impure and of a buffish color, being magnesian, and occasionally a good cement rock, as at Uniontown, Pennsylvania. This is the only member of the "Great" Limestone which appears to be persistent from the Pennsylvania line southward across West Virginia to the Big Kanawha River, since an impure limestone only 2 to 5 feet thick occurs at this horizon in the vicinity of Raymond City and other points in that region.

In the Salisbury basin this limestone occurs only 160 feet above the Pittsburgh coal, and is 10 to 12 feet thick, according to Platt.

THE "GREAT" LIMESTONE.

This name, given by Rogers, is generally applied to all of the great mass of lime deposits which intervene between the Uniontown and Sewickley coals, though, as already stated, the name Uniontown is now given to the uppermost division of the same.

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At many localities in Greene, Washington, Fayette, and Monongalia Counties there are nearly 160 feet of limestones and limy shales at this horizon, and the same beds hold their place, though with diminished thickness, across to the Ohio River at Wheeling. Westward and southward, however, from Ohio and Marion Counties, these limestones disappear very rapidly, so that at Clarksburg on the one hand, and westward through Ohio on the other, they have practically disappeared, and in their stead we find shales, gray at first, but gradually getting reddish toward the Little Kanawha River and the western margin of their outcrop in Ohio. On the Big Kanawha much red shale occurs at this horizon. These limestones are of different qualities, some of the layers being quite pure and forming good fluxes for iron, while others are magnesian and make excellent hydraulic cements.

The only fossils ever seen in any of these limestone beds are fish remains and minute ostracoids.

THE SEWICKLEY SANDSTONE.

At many localities where the "Great" Limestone is well developed there are no other beds except limestones and shales in all of the interval between the Uniontown and Sewickley coals, but in other regions a sandstone frequently makes its appearance just above the Sewickley coal. This has been called the Sewickley sandstone, and while it is often flaggy, yet again it becomes massive, and even pebbly, varying in thickness from 20 to 60 feet. Its massive character is well shown along the Monongahela River between Morgantown and Fairmont, in the vicinity of the Big Falls.

THE SEWICKLEY COAL.

Directly under the Sewickley sandstone, or in its absence the "Great" Limestone, there comes the Sewickley coal, a bed which is widely persistent, though the area where it is valuable is not so large.

The bed attains its maximum thickness and importance along the Monongahela River in Greene, Monongalia, and Marion Counties, being there 5 to 6 feet thick, with only one slate parting of 2 to 3 inches near the center. The coal is generally high in both ash and sulphur, but is open-burning and makes a rather fair domestic fuel.

The following represents the general structure of this bed along the Monongahela River in Marion and Monongalia Counties:

	Ft.	in.	
Coal	2	8	5′ 6″
Slate	0	2	
Coal	2	8	

Followed down the Monongahela River, the bed retains about the same structure as far as the mouth of Whitely Creek, Greene County, Pennsylvania, when the slate partings thicken up, and new ones come in and dissipate the coal in several thin layers through 25 feet of rock

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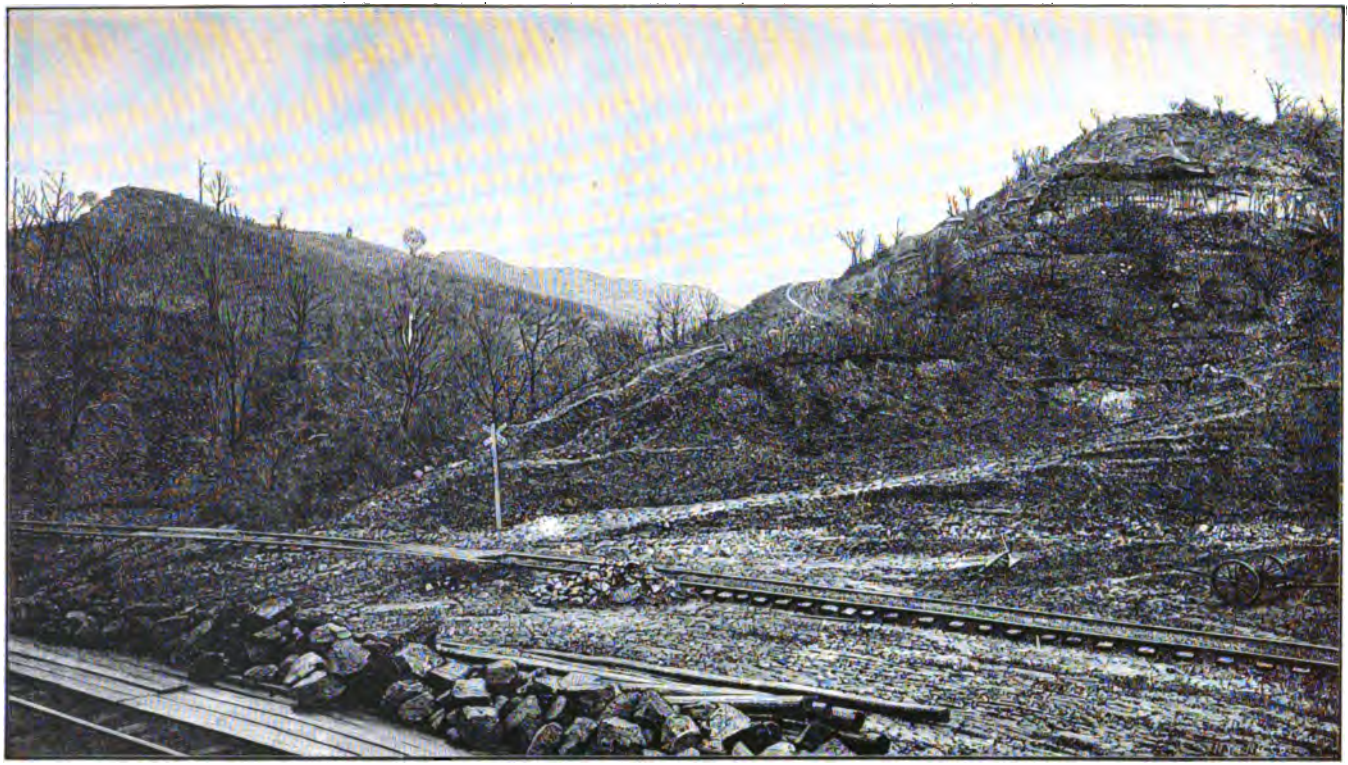

UPPER COAL MEASURES AT POINT PLEASANT, WEST VIRGINIA, SHOWING RUGGED CHARACTER OF THE TOPOGRAPHY.

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material, and from thence on down that river it is of no importance. But followed in the other direction, up the Monongahela, this bed holds a thickness of 5 to 6 feet through Marion County until the Harrison County line is approached, when it again splits up into three or four divisions separated by several feet of shales and slates, and when Clarksburg is reached there remains only 1 foot of coal at this horizon (Section 18), which soon disappears entirely toward the southwest.

From the Monongahela region this coal dips down westward under the great mantle of Permo-Carboniferous beds, and when it reappears on the Ohio River, in the vicinity of Wheeling (Section 19), Bellaire (Section 20), and Pipe Creek (Section 22), we find it split up again into three or four layers, and the separating slates several feet thick, thus giving the whole bed a thickness of 20 to 30 feet, with the main coal layer at the top.

This uppermost division of the Sewickley is separated from the Pittsburgh below by an interval of 80 to 100 feet, and attains considerable importance in the counties of Belmont, Harrison, Guernsey, Monroe, Morgan, Muskingum, Noble, etc., and has there been mined under a variety of names, among which are "Upper Barnesville," "Upper Bellaire," "Cumberland," "Meigs Creek," and several others. Prof. Orton, while intimating its identity with the Sewickley of Pennsylvania (Vol. V, page 1059, Ohio Geology), prefers to call it by the name of Meigs Creek, from a stream in Morgan County along which it is well developed.

Throughout much of this Ohio region the coal is 3 to 4½ feet thick, and nearly always has a clay or bony streak near its center. It also frequently has a rider coal in the roof, and the entire bed is rather rich in ash and sulphur, according to Orton.

In Fayette County, Pennsylvania, the Sewickley coal has a thickness of 4 to 5 feet through several townships, according to Stevenson, but northward through Westmoreland it thins down and is unimportant. It is scarcely known in the Ligonier basin, but in that of Salisbury is 2 feet thick and 90 feet above the Pittsburgh.

In the Georges Creek basin of Maryland and West Virginia the bed is 5 to 7 feet thick, 90 to 115 feet above the Pittsburgh, and an excellent coal for steam purposes.

The oil-borings across Monongalia and Marion Counties reveal this coal present in good thickness 10 to 15 miles west from the Monongahela River, and 100 to 110 feet above the Pittsburgh coal. The oil drillers usually call it the "Mapletown" coal, from a locality in Greene County where it is mined.

THE SEWICKLEY LIMESTONE.

Th interval between the Sewickley coal and the one next below is often occupied largely by limestone, especially in Greene, Fayette, Washington, Monongalia, and Marion Counties, and to the one which

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comes next below the coal Messrs. Platt have given the name Sewickley. It has also been termed the Fishpot Limestone by Stevenson, from a small stream in Washington County. I have deemed it preferable to apply the name Sewickley to the whole limestone group which lies between the Sewickley and Redstone coal beds. This interval is 40 to 60 feet thick and sometimes contains two beds of sandstone intercalated with the limestones. Along the Monongahela River in Greene, Monongalia, and Marion Counties, these limestones are well developed, and many of the layers furnish excellent lime for mortar and agricultural uses, while near the base of the group occur some excellent limestone flags at Laurel Point, Monongalia County.

The only fossils ever noted in these beds are minute fresh-water types.

These limestones disappear southward from Harrison County, West Virginia, there being only 9 feet of them in the Clarksburg section, and none on the Little and Big Kanawha Rivers. The same thing takes place in Ohio, westward from Washington County, the interval being occupied by shales and sandstones.

In Pennsylvania this Sewickley limestone holds a prominent place eastward from Washington and Greene, through Fayette, Westmoreland, and Somerset Counties.

THE REDSTONE COAL.

In Fayette County, Pennsylvania, a small coal was found cropping out along Redstone Creek, at an interval of 40 to 45 feet above the Pittsburgh, and this was named from that stream by the geologists of the First Pennsylvania Geological Survey.

Monongalia is the only county in West Virginia where this bed is workable, it being there, on Scott's and Robinson's Runs, 4 to 5 feet thick and of fair quality, though having rather too much sulphur and ash for manufacturing purposes. It is also workable in several townships of Fayette and Westmoreland, being 3 to 4 feet thick. In the Salisbury basin of Somerset County, Messrs. Platt identify the Redstone coal as a slaty bed, 4 feet thick, at 45 feet above the Pittsburgh. It has not been reliably reported from the Georges Creek field unless it be represented by one of the rider layers in the roof of the Pittsburgh bed.

In the vicinity of Wheeling, Bellaire, and other points on the Ohio River, this bed is only a few inches thick, never becoming workable anywhere in Ohio.

Through central West Virginia, beyond the Little Kanawha, its presence is unknown except by a bed of black slate which is occasionally seen at this horizon.

THE REDSTONE LIMESTONE.

At many localities along the Monongahela River in Harrison, Marion, Monongalia, Greene, Washington, Fayette, and Westmoreland Counties, there occurs a bed of limestone often 10 to 20 feet thick, and im-

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mediately underlying the Redstone coal. From this latter fact it was termed the Redstone limestone by Messrs. Platt, who find the same bed in Somerset County, 40 to 45 feet above the Pittsburgh coal. It often contains several layers, which make fairly good lime for many purposes, and is occasionally used for flux in iron furnaces.

This limestone is also in great force in the vicinity of Wheeling, Bellaire, and vicinity, where it occupies nearly the entire interval between the Redstone and Pittsburgh coals, and is extensively quarried as a flux for the furnaces there.

It, like all the other limestones, disappears southwestward through West Virginia, and is not known beyond the Little Kanawha River.

THE PITTSBURGH SANDSTONE.

Very frequently, and especially when the Redstone limestone is well developed, there is nothing but shales intervening between it and the Pittsburgh coal, but when the limestone is absent, or but poorly represented, there is often present a coarse, massive sandstone immediately above the Pittsburgh coal, and to this Mr. H. D. Rogers long ago gave the name of Pittsburgh sandstone. It varies in thickness from 25 up to 70 feet, and is usually coarse, friable, and often pebbly. Good building stone has never been obtained from it, since it yields so readily to atmospheric agencies.

This rock is especially massive in the vicinity of Hartford City, Pomeroy, and other contiguous regions, and the same may be said of the eastern line of its outcrop from Pennsylvania clear across West Virginia to the Kentucky border.

In the Georges Creek, Salisbury, and Ligonier basins, however, this rock makes but little show in the topography, its place being occupied by soft shales.

THE PITTSBURGH COAL.

The last and lowest member of the Upper Coal Measures is the celebrated Pittsburgh bed, the most important mineral deposit of the Appalachian field.

It was formerly thought that this coal bed was entirely persistent; that wherever its horizon was to be found, there the coal might be expected with absolute certainty. This generalization, however, was founded on data obtained only from the northern half of its area. In Pennsylvania, for instance, no area has yet been discovered where, at the proper geological horizon for this bed, it does not exist. Even in central Greene, at a depth of 1,500 feet below the Permo-Carboniferous summits, the drill of the petroleum seeker invariably finds this coal bed, while the isolated peak of Round Top, in the Broad Top coal basin of Bedford County, 50 miles distant from any other outcrop of the coal, likewise contains it. But when we pass southwestward across the West Virginia and Ohio coal field, Pennsylvania conditions of course continue

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for many miles, but ultimately there comes a change, and when we look for the Pittsburgh bed it is gone, or so reduced in thickness that the geologist can only recognize it by its associated rocks. The region of country covered by this barren area is quite extensive, and seems to be rudely coincident with the line of the Volcano or Burning Springs anticlinal of West Virginia.

The following counties in that State have the coal but poorly developed or wanting at the horizon where it belongs: Calhoun, Roane, Wirt, Ritchie, Pleasants, and Wood. This belt projected northward through Ohio takes in the counties of Washington, Noble, and Morgan, in all of which the coal is thin or wanting altogether. Thus it happens that over a belt of country 30 to 50 miles wide, and running nearly north and south across the Appalachian coal field, the spread of this bed, so even and persistent at the north, is here irregular, interrupted, and wanting. West from this belt the coal comes in again and is fairly regular in parts of Kanawha, Putnam, and Mason Counties, east from the Big Kanawha; but west from that stream the bed is thin, patchy, and of little importance through Cabell and Wayne, till it disappears from the center of the great Appalachian trough in the hilltops overlooking the Big Sandy River.

In Ohio, also, a considerable area of this coal comes in west from the barren belt, and extends through Meigs and Athens Counties with fairly good thickness, but westward from them, in Gallia, the coal is again thin and uncertain.

The foregoing sections, Nos. 11 to 32 inclusive, show in a general way the detailed structure of the Pittsburgh coal, so that only a few others need be given in this connection to exhibit its structure in every important region of its widely extended area.

As will be seen from these sections, the coal is nearly always separated into two well defined portions (the roof and the main bench) by a layer of clay, and there are often several divisions of the roof, as also of the main bench. The layers of coal in the roof are usually not more than 1 to 1½ feet thick, and separated by shales of about the same thickness, while the divisions of slate in the main bench are mere knife edges, seldom exceeding an inch in thickness and generally not more than half that amount.

Along the Monongahela River, two of these slates are especially constant, since they come about 2½ to 3 feet above the bottom of the bed and are 4 to 6 inches apart. They are usually known as the "bearing in" slates, and are seldom more than one-half inch thick. Then 1 to 1½ feet below these there is generally another thin parting of slate which runs through the bed with great persistency, dividing the lower portion into two layers known by the miners as the "brick" coal, and "bottom" coal. Of course there are other partings which occasionally make their appearance in the bed at some localities, but they are irregular and not persistent.

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THE PITTSBURG COAL OUTCROP NEAR CONNELLSVILLE, PENNSYLVANIA, SHOWING COLUMNAR STRUCTURE OF TYPICAL COKING COAL.

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Section at Newburg, West Virginia.—The summits around Newburg, Preston County, West Virginia, catch small areas of this bed in the syncline between the Chestnut Ridge and Laurel Hill anticlinals, and the coal has there the following structure:

	Ft.	in.	Ft.	in.	Ft.
Pittsburgh sandstone					
Slaty coal	0	8	4	3	15
Shale	0	9			
Coal	0	10			
Shale and fire clay	2	0			
Coal	9	0	10	9	
Slate	0	3			
Coal, slaty	1	6			

Section at Copeman's Knob, West Virginia.—In the next trough east of the Laural Hill anticlinal, a small isolated area of the Pittsburgh coal is caught in Copeman's Knob, which overlooks Cheat River at the foot of Briery Mountain, near Albrightsville, Preston County, West Virginia, and there the coal shows this structure:

		Ft.	in.	Ft.	Ft.
Roof.	Shales				
	Coal	2	0	9	19
	Slate	1	6		
	Coal, slaty	2	4		
	Slate	0	2		
	Coal	1	6		
	Clay	1	6		
Main coal, partings not visible				10	

Section 32 gives the structure of this coal still farther eastward in the Georges Creek basin, and it, when compared with the Albright, Newburg, and Fairmont (Sec. 17) structures, shows a gradual eastward thickening of the bed from 7 feet on the Monongahela to 20 at many points in the Georges Creek field.

Section at Fairfax Knob, Tucker County, West Virginia.—Near the southern end of the Georges Creek basin, at the head of the North Potomac River, a small area of the Pittsburgh bed is caught in the summit of Fairfax Knob, 3,250 feet above tide, and 20 miles distant from any other outcrop of the coal. The main portion of the bed is here split into three portions, separated by several feet of shales, from the thickening up of the parting slates, as follows:

		Ft.	in.	Ft.	in.	Ft.
Roof.	Shales					
	Coal	2	0			8
	Shale	6	0			
Coal, "breast".	Coal	8′	2″	9	6	55
	Slate	0′	2″			
	Coal	1′	2″			
Shales		5′	0″	16	0	
Limestone		4′	0″			
Shales		7′	0″			
Coal, "brick"				4	6	
Fireclay and shales				18	0	
Coal, "bottom," slaty				7	0	

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As will be seen from the above, it would appear that the three main divisions of the Pittsburgh bed, viz, "breast," "brick," and "bottom," are here separated by shales, 16 and 18 feet thick respectively, instead of mere partings of a fraction of an inch, as on the Monongahela and elsewhere, thus spreading the 21 feet of coal through an interval of 55 feet. It is also worthy of note that although the partings have here increased so wonderfully, yet the total thickness of coal remains the same as in the central part of the Georges Creek Basin.

In the vicinity of Glenville, on the Little Kanawha River, this coal is 4½ to 5 feet thick, with a bony streak 16 inches below the top of the bed.

The structure on the Big Kanawha is given in Section 31.

Section at Huntington, Cabell County, West Virginia.—In the summits of the hills south of Huntington, Cabell County, West Virginia, this coal displays the following structure:

	Ft.	in.	Ft.	in.
Coal	0	6	4	8
Clay	0	6		
Coal	3	6		
Slaty coal	0	2		

The farthest point to the southwest that this bed has ever been seen is in the summit of a hill overlooking the Big Sandy River, 10 miles above its mouth, where a small patch is caught in the center of the Appalachian trough, which, rising to the southwest, carries the coal above the highest hills on the Kentucky side of the Big Sandy. The coal is here 3 feet 2 inches thick and single bedded, or with only faint partings.

Section at Pomeroy, Meigs County, Ohio.—At Pomeroy, Ohio, the Pittsburgh coal shows thus, according to Prof. E. Lovejoy, Ohio Geological Survey, Vol. VI, page 636:

	In.	Ft.	in.
Coal	8–14	5	10
Horn coal	3		
Coal	42–47		
Clay	4		
Coal	7		

Section on Shade Creek, Ohio.—In the Shade Creek coal field of Meigs and Athens Counties, Ohio, Prof. Lovejoy finds a well developed rider coal 12 to 20 feet above the main bed, and often mined separately from it. The two have the following structure:

	Ft.	in.	Ft.	in.
Coal	0	6	2	8
Slate	0	4		
Coal	1	10		
Shales		12–20		
Coal	0	9	4	3
Slate, streak	0	0		
Coal	2	6		
Slate, streak	0	0		
Coal	1	0		

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Section on Federal Creek, Ohio.—In the Federal Creek field of Athens and Morgan Counties, Ohio, the coal shows as follows (Lovejoy), op. cit., p. 648, Heyburn Brothers & Co.'s mine, Berne Township, Athens County:

	Ft.	in.	Ft.
Coal	1	10	10
Slate, streak	0	0	
Coal	2	4	
Slate	0	7	
Coal	0	3	
Clay	1	0	
Coal	1	0	
Slate, streak	0	0	
Coal	3	0	

Section at Berry's mine, Ohio.—Berry's mine, in Homer Township, Morgan County (op. cit. page 650), gives the following:

	Ft.	in.	Ft.	in.
Coal	0	11	5	4
Slate, streak	0	0		
Coal	3	5		
Clay	1	0		
Coal	0	4½	3	7½
Slate, streak	0	0		
Coal	0	7½		
Slate, streak	0	0		
Coal	1	10		
Slate, streak	0	0		
Coal	0	9½		

The clay stratum in these and other mines appears to correspond to the main clay parting which always separates the roof coals of the Pittsburgh bed from the main bench along the Monongahela, and the 12 to 20 feet of shales which separate the two coal beds in the Shade Creek field would appear to belong at the same horizon.

East from the barren area of the Pittsburgh coal of Morgan, Noble, and Washington Counties, Ohio, it comes in again with a fine development in Belmont, Harrison, and Jefferson.

Section in Belmont County, Ohio.—The following section from Ohio Geology, Vol. VI, page 621, exhibits the structure in the southern portion of Belmont County, Washington Township, as given by Prof. Brown:

	Ft.	in.	Ft.	in.
Coal	1	0	1	11
Clay	0	10–12		
Coal	2	9	6	0
Slate	0	0½		
Coal	2	0		
Slate	0	0½		
Coal	1	2		

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Section at Bellaire, Belmont County, Ohio.—In Bellaire the following is shown at Heatherington's mine:

	Ft.	in.	Ft.	in.
Coal	1	0	3	2
Black slate	0	4		
Coal	1	0		
Clay	0	10		
Coal	2	6	6	0½
Slate	0	0		
Coal	0	5		
Slate	0	0		
Coal	1	9		
Black slate, pyritous	0	0½		
Coal	1	0		
Hard, slaty coal	0	4		

Section in Jefferson County, Ohio.—In Warren Township, Jefferson County, Ohio, this coal has the following structure (Brown, Ohio Geology, Vol. VI, page 603):

	Ft.	in.	Ft.	in.
Roof coal	2	3	2	7
Clay	0	4		
Coal	2	2	4	11
Clay parting	0	2		
Coal	0	2		
Black slate	0	½		
Coal	1	3		
Parting				
Coal	1	2		

Section in Harrison County, Ohio.—In German Township, Harrison County, Ohio, Stevenson reports the Pittsburgh coal as follows (Ohio Geological Survey, Vol. III, p. 212):

	Ft.	in.	Ft.	in.
Roof coal, not exposed	0	0		
Coal	1	9	4	9½
Parting	0	0½		
Coal	0	6		
Parting	0	1½		
Coal	1	2		
Parting	0	0½		
Coal	1	2		

Section at Columbia mine, Westmoreland County, Pennsylvania.—As a typical section of this coal on the Monongahela River with reference to the structure of the main bench and roof, we may take that found at the Columbia mine, near Webster and 36½ miles above Pittsburgh, as given by Mr. J. Sutton Wall (K⁴, Pennsylvania Geological Survey, p. 50):

	Ft.	in.	Ft.	in.
Roof coals, in seven divisions	3	9	4	3
Over-clay	0	6		
"Breast" coal	3	8	6	6½
Parting	0	0½		
"Bearing in" coal	0	3		
Parting	0	0½		
"Brick" coal	1	2		
Parting	0	0½		
"Bottom" coal	1	4		

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A careful comparison of the structure of this famous bed at a great many points very widely separated exhibits such a striking resemblance to that just given above that we can scarcely attribute it to chance, but must find the explanation in the prevalence of nearly uniform conditions over the immense area covered by the Pittsburgh marsh.

The great excellence of this coal for steam and domestic purposes, and also for the manufacture of gas and coke, combine to render it the most valuable bed of coal in the entire Appalachian field.

Page plate 6 gives a view of this bed at Connellsville, the center of the coke-making industry, and in this the peculiar columnar structure of a typical coking coal is fairly shown.

It was formerly believed that this bed would not make first-class coke over any large area outside of the Connellsville basin, but recent developments along the Monongahela River in Marion and Monongalia Counties, West Virginia, have proved this belief erroneous, since it is there successfully coked on a large scale.

By crushing and washing, where there is too much sulphur present, there is no reason why this bed will not make coke equal to that of the Connellsville, throughout all of the region south and west from the latter.

The roof coals of this bed are never mined; not because they do not furnish good fuel, but because they are always interstratified with shale, which renders the mining difficult. These roof layers often amount to 3 or 4 feet of good coal, and thus this large quantity of fuel is continually wasted, though the time will doubtless come in the distant future when the Pittsburgh bed will be mined over again for the coal now neglected in its roof and bottom.

FOSSILS OF THE UPPER COAL MEASURES.

The flora of the Pittsburgh roof shales as well as of the entire Upper Coal Measures is very meager, and only a few of the very common types, like *Neuropteris hirsuta*, *N. flexuosa*, and *Pecopteris arborescens*, are usually found, while the fauna of the whole group, so far as known at present, seems to be restricted to fresh water types.

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CHAPTER IV.

THE BARREN MEASURES, OR ELK RIVER SERIES.

THICKNESS, CHARACTER, AND EXTENT.

Below the Pittsburgh bed we descend into a very natural group of rocks (No. XIV) which was long ago clearly recognized by the Rogers brothers in both Pennsylvania and Virginia. The group as defined by them extended from the base of the Pittsburgh coal down to the top of the Mahoning sandstone, and was called the Lower Barren Measures; but subsequent investigation seems to render it more desirable to extend the group downward so as to include the Mahoning sandstone. This brings the group within the definite limits of two important and very persistent coal beds, the Pittsburgh above and the Upper Freeport below; and hence, for purposes of comparison, study, and all the uses which classification subserves, is more desirable than the old system, since the top of the Mahoning sandstone is too variable a quantity for the limit of any group.

I have already indicated in a previous chapter that a larger view of the Carboniferous Measures, which overlooks details invaluable for classification to the working geologist, would run a line through the middle of the Barren Measures, and call everything above it, to the top of the Dunkard Creek series, Upper Carboniferous; that below it, to the base of the Pottsville conglomerate, Middle Carboniferous, and the rest down to the Catskill, Lower Carboniferous. Such a classification of the Appalachian Carboniferous may be useful for comparison with the Carboniferous system in other regions and countries, but it is too general for the practical geologist, and can never supplant that which has stood the test of long and continuous use. Hence we deem it best to retain the limits of the Barren Measures intact, with the slight modification just suggested, and already long in use by the Second Geological Survey of Pennsylvania.

I have adopted the name Elk River series as a geographical designation for these beds, since they are very finely exposed along that stream between its mouth at Charleston, West Virginia, and Braxton Court-House, or Sutton, nearly 100 miles above.

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This series, as thus limited above and below by important coal beds, consists of two very different members; an upper one composed largely of shales, therefore soft, easily eroded, and always making rounded hills and rolling topography; the other, or lower, composed largely of massive sandstones which resist erosion and thus form steep cliffs, deep gorges, rugged topography, and wild scenery generally.

These sand rocks form a coping to the Lower Coal Measure hills, and cap the summits long after the soft beds above have disappeared.

The soil formed by the soft member, while rather thin and not to be compared in fertility to that of the Upper Coal Measures, yet with care and a liberal use of lime yields excellent crops and always makes good grazing lands. But the lower portion, being almost destitute of lime, and containing so much sand, forms a very poor soil, on which only the scantiest crops can be grown.

The upper portion always contains a large percentage of red and marly shales, which make a broad band of red soil from Pennsylvania clear through central West Virginia, to and beyond the Kentucky line on the one hand, and thence circling around through eastern Kentucky and southern Ohio, back to Pennsylvania again on the other. These red clays are the fruitful source of landslides, bad roads, and many other troubles. They cave easily in drill holes, and thus give endless annoyance and expense to oil and gas drillers. Their tendency to slide causes much expense in cleaning out railroad cuttings, so that a proper knowledge of their character by engineers would lead to economy of money in building and maintaining both railroads and wagon roads.

The coal beds of this series are, with one or two exceptions, noted for their variableness and uncertainty. They may be in fair development on one farm, and absent entirely on the adjoining one. They are also usually rich in ash and poor in carbon, and although they are patchy in their distribution, yet the main beds appear to maintain the same horizons in the stratigraphy, and can thus be identified with reasonable certainty over wide areas. The sandstones found within the limits of this group are of more economic importance than the coal beds, since the former nearly always furnish most excellent building stone, while the latter are commercially valuable only over limited areas. Iron ore in valuable quantity exists locally at several horizons in the Barrens, and these will be referred to hereafter in detail.

The limestones of this series, like the coals, are generally thin and impure, so that they are of more importance in determining the stratigraphy than for economic purposes.

The entire thickness of the group varies much in different portions of the Appalachian field, reaching a maximum of 800 feet in the vicinity of Charleston, West Virginia, while along the northwestern outcrop of the beds in Ohio the minimum is not much above 300 feet.

In Pennsylvania and northern West Virginia the average is about 600 feet, but it sometimes runs up to 650 and down to 550.

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The following sections, taken in the several portions of the Appalachian field, will serve to illustrate both the changing thickness of the series and the variable nature of the individual beds.

Section in the Pittsburgh region.—We shall begin the list at Pittsburgh, where the upper half of the Barrens is finely exposed, and the numerous carefully kept records of drill holes have revealed the constitution of the lower half, so that by uniting the two we get the following (Fig. 33):

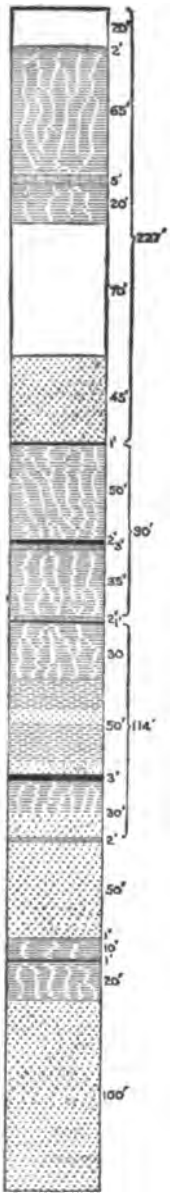

FIG. 33.—Section in the Pittsburgh region.

In Pittsburgh region.

[See map, I m.]

	Ft.	Ft.
1. Pittsburgh coal		
2. Concealed	20	
3. Limestone	2	
4. Shales, variegated	65	
5. Limestone	5	227
6. Red shale	20	
7. Concealed	70	
8. Sandstone, Morgantown	45	
9. Coal, Elk Lick		1
10. Shales, variegated	50	
11. Coal	2	90
12. Limestone	3	
13. Shales, variegated	35	
14. Limestone, crinoidal		2
15. Coal, crinoidal	1	
16. Red and variegated shale	30	
17. Sandy shales and shaly sandstone	50	114
18. Coal, Bakerstown	3	
19. Shales and sandstone	30	
20. Limestone, Upper Cambridge		2
21. Sandstone, massive		50
22. Limestone, Lower Cambridge		1
23. Shales		10
24. Coal, Masontown		1
25. Shales		20
26. Sandstone, Mahoning		100
27. Upper Freeport coal.		
Total		618

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Section at Sewickley, Pennsylvania.—At Sewickley, Pennsylvania, a diamond-drill hole was put down by Mr. Cochran Fleming as a test for coal. The cores were carefully preserved, and from them I obtained a very accurate section of the lower portion of the Barrens, which, combined with the good surface exposures around Sewickley, gives the following structure (Fig. 34) for this series in that region:

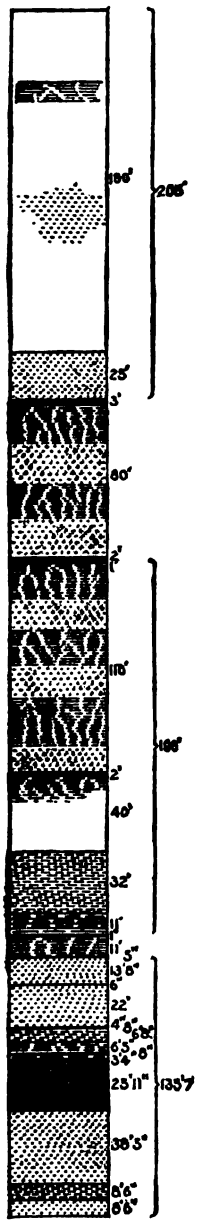

FIG. 34.—Section at Sewickley, Pa.

Sewickley, Alleghany County, Pennsylvania.

[See map, H 1.]

		Ft.	in.	Ft.	in.
	1. Pittsburgh coal				
	2. Shales, sandstones, and concealed	180		205	
	3. Sandstone, Morgantown, massive	25			
	4. Coal, Elk Lick			3	
	5. Shales and sandstone			80	
	6. Limestone, crinoidal			2	
	7. Coal, crinoidal	1		196	
	8. Red shales and sandy beds	110			
	9. Limestone, gray, Upper Cambridge	2			
	10. Shales and concealed	40			
	11. Sandy shale	32			
	12. Dark slate	11			
	13. Limestone, dark, Lower Cambridge			1	
	14. Dark shales			11	
	15. Coal, Masontown			0	5
Mahoning sandstone.	16. Sandstone, micaceous, gray	13	8	135	7
	17. Fire clay, sandy	0	6		
	18. Sandstone, light gray	22	0		
	19. Shale, dark gray	8	4		
	20. Sandstone, gray	0	8		
	21. Shale, sandy	6	8		
	22. Shale, blue	6	5		
	23. Sandstone	0	8		
	24. Slate, gray	3	4		
	25. Fire clay, variegated at base, impure	25	11		
	26. Sandstone, gray, micaceous	38	5		
	27. Shales, sandy, blue	8	6		
	28. Sandstone, light gray	8	6		
	29. Upper Freeport coal.				
	Total			634	

The interval No. 2 in this section was estimated, since the Pittsburgh coal is not found in the immediate vicinity of Sewickley, the highest stratum remaining there being the Morgantown sandstone, No. 3.

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Section on Dunbar Creek, Pennsylvania.—Eastward from the Pittsburgh region, we have a line of measurements of the Barren series which extend across the Alleghanies. The first one is in the adjoining county of Fayette, at the foot of Chestnut Ridge, made by Prof. Stevenson and published in his Report KK, page 182. It is as follows (Fig. 35):

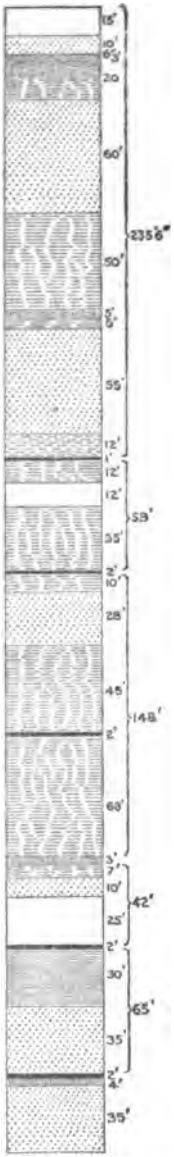

FIG. 35.—Section on Dunbar Creek, Pa.

Dunbar Creek, Fayette County, Pennsylvania.

[See map, K n.]

	Ft.	in.	Ft.	in.
1. Coal, Pittsburgh				
2. Concealed	15			
3. Sandstone	10			
4. Coal, Little Pittsburgh	0	6		
5. Clay	3			
6. Limestone and shale	20			
7. Sandstone, Connellsville	60		235	6
8. Shales	50			
9. Limestone	5			
10. Shale	5			
11. Sandstone, Morgantown	55			
12. Shale, sandy	12			
13. Coal, Elk Lick			1	
14. Shale	12			
15. Concealed	12		59	
16. Shale, variegated	35			
17. Coal, clay, crinoidal			2	
18. Shales, brown	10			
19. Sandstone	28			
20. Shale	45		148	
21. Coal, Bakerstown	2			
22. Shale	63			
23. Limestone, Lower Cambridge			3	
24. Shale	7			
25. Sandstone, argillaceous	10		42	
26. Concealed	25			
27. Coal, Masontown			2	
28. Clay	30		65	
29. Sandstone, Upper Mahoning	35			
30. Coal, Mahoning			2	
31. Fire clay			4	
32. Sandstone, Lower Mahoning			35	
33. Coal, Upper Freeport.				
Total			598	6

The identification of the Lower Cambridge limestone in the above section is open to question, but the probabilities are in favor of the one given.

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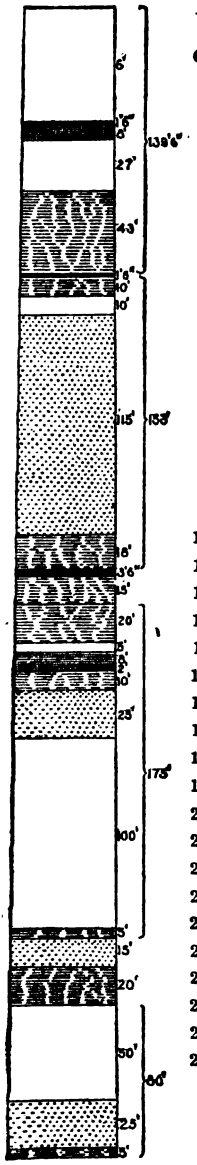
Section at Ligonier, Pennsylvania.—Eastward from the last locality, and between Chestnut Ridge and Laurel Hill, the following section (Fig. 36) of these beds was measured at Ligonier, Westmoreland County, Pennsylvania, by Prof. Stevenson, as given in Report KKK, page 129:



Ligonier, Westmoreland County, Pennsylvania.

[See map, J p.]

	Ft.	in.	Ft.	in.
1. Pittsburgh coal				
2. Concealed	60			
3. Coal, Little Pittsburgh	1	6		
4. Limestone	8		139	6
5. Concealed	27			
6. Shale, variegated	43			
7. Coal, Little Clarksburg			1	6
8. Shale	10			
9. Concealed	10			
10. Sandstone, Morgantown	115		153	
11. Shale, olive	18			
12. Coal, Elk Lick			3	6
13. Shale			15	
14. Limestone, green, fossiliferous				
15. Shale	20			
16. Sandstone	5			
17. Clay	8			
18. Limestone, ferruginous	2			
19. Shale	10		175	
20. Sandstone	25			
21. Concealed	100			
22. Shale	5			
23. Sandstone, Upper Mahoning			15	
24. Shale			20	
25. Coal, blossom, Mahoning				
26. Concealed	50			
27. Sandstone, Lower Mahoning	25		80	
28. Shale	5			
29. Coal, Upper Freeport.				
Total			602	6

3. 36. — Section at Ligonier, Pa.

This and the preceding section, as well as the one which follows, illustrate in a remarkable manner the pid variation in the individual elements of the Barrens, while the tal thickness remains almost exactly the same.

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Section near Berlin, Pennsylvania.—Still farther east, in the Berlin basin of Somerset County, Pennsylvania, and on the very summit of the Alleghany Mountains, we find this series with the following structure (Fig. 37) as determined by Messrs. Platt, with some additions and modifications by the writer:

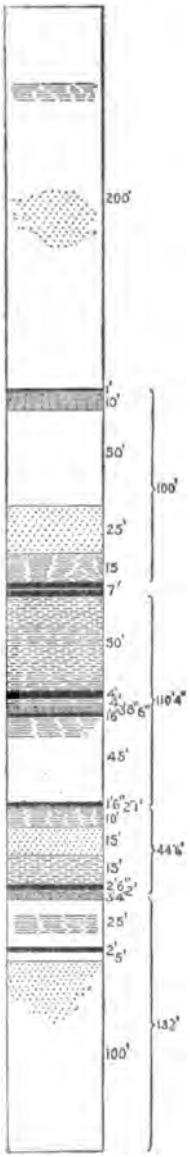

FIG. 37.—Section near Berlin, Pa.

Vicinity of Berlin, Somerset County, Pennsylvania.

[See map, K p.]

		Ft.	in.	Ft.	in.
1.	Pittsburgh coal				
2.	Interval, shales, sandstones, etc			200	
3.	Coal			1	
4.	Limestone, gray and buff	10			
5.	Concealed	50		100	
6.	Sandstone, massive	25			
7.	Shales, dark	15			
8.	Coal, Platt (crinoidal) { Cannel slate....1'; Coal, slaty.....2'; Shale.....1'; Coal.....3' }			7	
9.	Sandy shales and black slates	50			
10.	Coal, Price (Bakerstown) { Coal.....3' 2"; Slate.....0' 4"; Coal.....0' 6" }	4			
11.	Slates, dark	4			
12.	Limestone, dark gray { Limestone..1' 8"; Slate.....0' 8"; Limestone..1' 4" }	3	8	110	4
13.	Shale	0	6		
14.	Coal	1	6		
15.	Shales, and concealed	45			
16.	Coal, Coleman	1	6		
17.	Slate, dark	0	2		
18.	Limestone, Coleman (Upper Cambridge)			1	
19.	Shales	10			
20.	Sandstone, and concealed	15			
21.	Shales, sandy	15			
22.	Coal, Philson { Coal.....1' 3"; Slate, black.....0' 9"; Coal.....0' 6" }	2	6	44	6
23.	Fire clay	2			
24.	Limestone, Philson (Lower Cambridge) { Limestone, dark .1' 0"; Shale, black .....0' 4"; Limestone.....2' 0" }			3	4
25.	Concealed, and shales	25			
26.	Coal, Masontown	2		132	
27.	Concealed	5			
28.	Sandstone, Mahoning, and concealed	100			
29.	Coal, Upper Freeport.				
	Total			599	2

Section at Broad Top, Pennsylvania.—As showing the remarkable persistence of this series in its general thickness over the Pennsylvania

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field, we give another measurement (Fig. 38) from far east of the Alleghany Mountains, in the center of the Broad Top Basin, Bedford County, Report T², Stevenson, page 60:

FIG. 38.—Section at Broad Top, Pa.

Broad Top, Bedford County, Pennsylvania.

[See map, J t.]

	Ft.
1. Pittsburgh coal	
2. Poorly exposed (shales and sandstones)	425
3. Sandstone, Upper Mahoning	50
4. Coal, Mahoning	5
5. Clay	3
6. Sandstone, Lower Mahoning	40
7. Coal, Upper Freeport.	
Total	523

Section opposite Steubenville, Ohio.—The next line of sections in this series across the Appalachian field will begin at Steubenville, on the Ohio River, and keeping south of the former line, end at Davis, Tucker County, West Virginia. The following succession (Fig. 39) was obtained opposite Steubenville by combining the surface observations with the records of drill holes and shafts:

Opposite Steubenville, Ohio.

[See map, I j.]

	Ft.	Ft.
1. Pittsburgh coal		
2. Shales, sandstone, and concealed	100	
3. Shales	15	200
4. Sandstone, massive, Morgantown	85	
5. Limestone, fossiliferous, crinoidal		10
6. Red shales	40	
7. Concealed, with shales and flaggy sandstone	100	142
8. Coal	1	
9. Shale	1	
10. Limestone, fossiliferous, Lower Cambridge		2
11. Shales, drab	8	
12. Shales, with coal, Masontown	2	
13. Shales, gray	5	145
14. Sandstone, Mahoning, and concealed under river	130	
15. Coal, Upper Freeport.		
Total		499

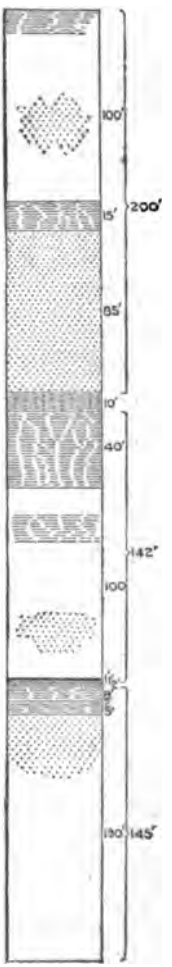

FIG. 39.—Section opposite Steubenville, Ohio.

This shows a westward thinning of about 100 feet for the series between Pittsburgh and Steubenville.

Section under Washington, Pennsylvania.—Near Washington, Pennsylvania, many wells drilled for gas and oil have revealed the structure of the Barren Measures, although they lie many hundred feet below the surface.

One of these borings was supervised by Prof. Linton, of Washington and Jefferson College, and from the record thus obtained of the Thayer oil well, as

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published in Pennsylvania Geological Report, 1886, page 764, we get the following for the Barrens there (Fig. 40):

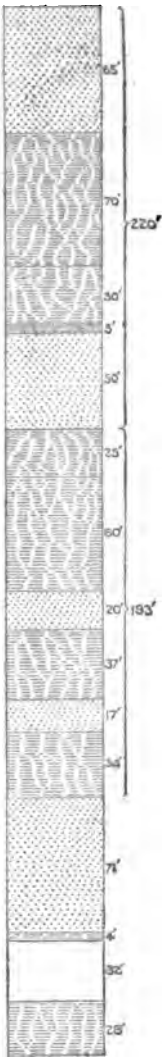

Fig. 40.—Section at Washington, Pa.

Washington, Pennsylvania.

[See map, J k.]

	Ft.	Ft.
1. Coal, Pittsburgh		
2. Sandstone	65	
3. Shale, black and red	70	
4. Shale, red	30	220
5. Limestone	5	
6. Sandstone, Morgantown	50	
7. Shale, black	25	
8. Shale, red and variegated	60	
9. Sandstone, hard	20	193
10. Shale, black	37	
11. Sandstone	17	
12. Shale, red, variegated	34	
13. Sandstone, Upper Mahoning		71
14. Shale, olive green		4
15. Sandstone, Lower Mahoning { gray, fine flaggy .. 15′; white ..... 17′ }		32
16. Shale, dark, to place for Upper Freeport coal		28
Total		548

Nos. 8 and 12 are the beds which "cave" and give the oil drillers so much trouble.

Section near Cannonsburg, Pennsylvania.—In the vicinity of Cannonsburg, a few miles northeast from Washington, the record of a well drilled for gas on the Boyce farm, furnished me by Mr. Wm. S. Stevenson, assistant superintendent of the Philadelphia Natural Gas Company, gives the following (Fig. 41) as the structure of the Barrens there:

Near Cannonsburg, Washington County, Pennsylvania.

[See map, J l.]

	Ft.	Ft.
1. Coal, Pittsburgh		
2. Limestone, blue, hard	20	
3. Slate, white, soft	45	
4. Shale, red	36	
5. Slate, black	9	
6. Shale, red	47	225
7. Sandstone, gray, hard	10	
8. Slate, black	20	
9. Sandstone, gray, hard, Morgantown	38	
10. Shale, red	25	
11. Slate, black	5	
12. Sandstone, gray, hard	20	
13. Slate, white, soft	10	
14. Sandstone, gray, hard	20	
15. Slate, black	15	
16. Sandstone, gray, hard	10	190
17. Slate, black	25	
18. Sandstone, gray, hard	5	
19. Slate, black	10	
20. Sandstone, gray, hard	20	
21. Shells and slate, gray, hard	25	
22. Slate, black, soft		40
23. Slate, with coal, Mahoning		15
24. Shells, gray, hard		2
25. Slate, black, soft		40
26. Sandstone, white, hard, Lower Mahoning		45
27. Coal, Upper Freeport.		
Total		557

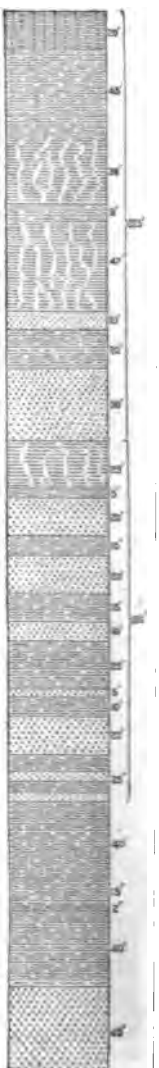

Fig. 41.—Section near Cannonsburg, Pa.

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Section at Morgantown, West Virginia.—From Washington across to Morgantown, West Virginia, the Barren Measures, as revealed by borings, hold about the same thickness as in Washington County. In the vicinity of Morgantown the entire column of the Barrens is exposed, and there the following structure is exhibited (Fig. 42):

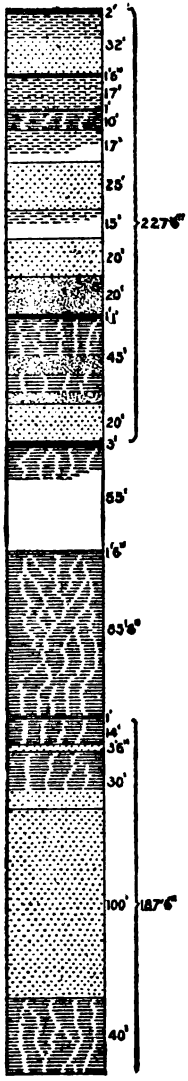

FIG. 42.—Section at Morgantown, W. Va.

Morgantown, Monongalia County, West Virginia.

[See map, M m.]

	Ft.	in.	Ft.	in.
1. Pittsburgh coal				
2. Fire clay	2			
3. Sandy shales and sandstone	32			
4. Coal, Little Pittsburgh	1	6		
5. Sandy shales	17			
6. Limestone	1			
7. Yellowish shales with iron ore	10			
8. Sandy shales, and concealed	17			
9. Sandstone, rather massive	25		227	
10. Sandy shales, and concealed	15			
11. Massive sandstone	20			
12. Bluish green sandy beds	20			
13. Black slate, fossiliferous	1			
14. Limestone, Clarksburg	1			
15. Shales and sandy beds	45			
16. Sandstone, Morgantown	20			
17. Elk Lick coal			3	
18. Shales, and concealed			55	
19. Limestone, crinoidal			1	6
20. Variegated shales			85	6
21. Limestone, Upper Cambridge			1	
22. Shales	14			
23. Sandstone, Upper Mahoning	3	6		
24. Shales and shaly sandstone	30		187	6
25. Massive sandstone, Lower Mahoning	100			
26. Shales	40			
27. Coal, Upper Freeport.				
Total			561	

The black fossiliferous slate, No. 13, represents the horizon of the Little Clarksburg coal, and is here filled with *fish teeth and scales.* The Upper Freeport coal is about 100 feet under the river at the Morgantown wharf, but southward it rises very rapidly and comes up to the bed of the river at the mouth of Coburn's Creek, 2 miles above. It is there about 4 feet thick and very pure.

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Section near Little Falls, West Virginia.—In the vicinity of Little Falls, Monongalia County, 9 miles above Morgantown, the basal members of the Barrens can be obtained more in detail than in the Morgantown section, and the following (Fig. 43) shows the structure there:

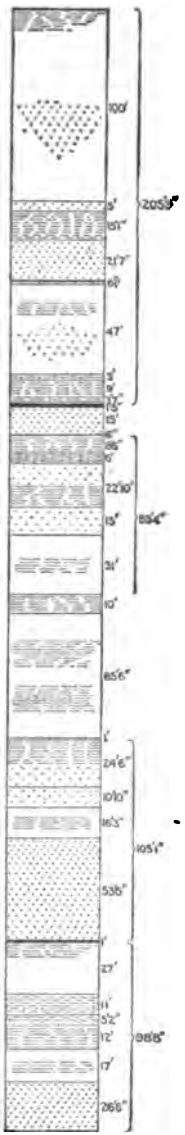

FIG. 43.—Section at Little Falls, W. Va.

Little Falls, Monongalia County, West Virginia.

[See map, M m.]

	Ft.	in.	Ft.	in.
1. Pittsburgh coal				
2. Shales, sandstones, and concealed	100			
3. Sandstone, in knob	5			
4. Shales	15	1		
5. Massive, coarse yellow sandstone	21	7		
6. Coaly shale, Little Clarksburg	0	6		
7. Limestone, fossiliferous, Clarksburg	1		205	9
8. Concealed, shales and sandstone	47			
9. Limestone, nodular	3			
10. Gray and yellow shales	9			
11. Black slate	3	7		
12. Coal, Elk Lick. { Coal { Coal 12″; Slate 1″; Coal 4″ } 1′ 5″; Concealed with red shale 15′; Coal, good 0′ 6″ }			16	11
13. Shales	8	6		
14. Limestone, gray and buff in several layers, Elk Lick	6			
15. Flaggy sandstones and shales	22	10	83	4
16. Sandstone, massive, pebbly at base for 4 feet	15			
17. Concealed, probably shales	31			
18. Fossiliferous shale, crinoidal			10	
19. Concealed, red shales and impure limestones			65	6
20. Limestone, light gray, Upper Cambridge			1	
21. Shales and flaggy sandstones	24	6		
22. Sandstone, rather massive	10	10		
23. Concealed, and shales	16	3	105	1
24. Sandstone, Upper Mahoning, massive	53	6		
25. Coal, Mahoning			1	
26. Shales and concealed	27			
27. Shale, greenish, sandy	11			
28. Sandy shale and flaggy sandstone	5	2		
29. Shale, greenish yellow	12		98	8
30. Concealed, probably shale	17			
31. Lower Mahoning sandstone	26	6		
32. Coal, Upper Freeport.				
Total			587	3

This section illustrates well the variability of the Barren Measures, when compared with the previous one, taken only a few miles distant.

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Section at Newburg, West Virginia.—The syncline between the Chestnut Ridge and Laurel Hill anticlines crosses the Baltimore and Ohio Railroad at Newburg, Preston County, West Virginia, about 15 miles east from Little Falls, and there the Barren Measures admit of vertical measurement by combining surface exposures with the record of the Orrel Coal Company's shaft. The result is as follows (Fig. 44):

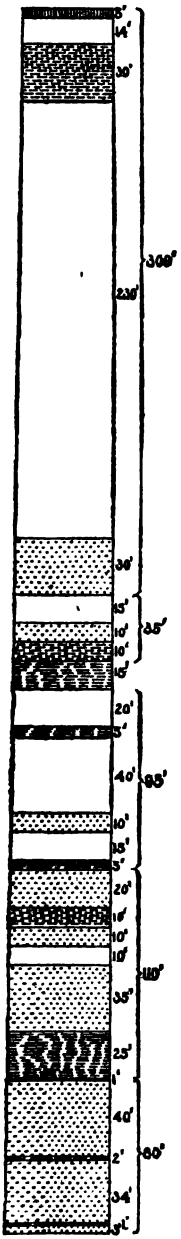

FIG. 44.—Section at Newburg, W. Va.

Newburg, Preston County, West Virginia.

[See map, N m.]

		Ft.	Ft.
	1. Pittsburgh coal		
	2. Fire clay	5	309
	3. Concealed	14	
	4. Shales, sandy	30	
	5. Concealed	230	
	6. Sandstone, pebbly, Morgantown	30	
	7. Concealed	15	35
	8. Sandstone, flaggy	10	
	9. Shales, sandy	10	
	10. Shales, dark, fossiliferous (crinoidal)		15
	11. Concealed	20	95
	12. Red, marly shale	5	
	13. Concealed	40	
	14. Sandstone, yellow	10	
	15. Concealed	15	
	16. Fire clay and shales	5	
Upper Mahoning.	17. Sandstone, massive	20	110
	18. Sandy shale	10	
	19. Sandstone, massive	10	
	20. Concealed	10	
	21. Sandstone	35	
	22. Shales	25	
	23. Coal, Mahoning		1
Lower Mahoning.	24. Sandstone	40	80
	25. Shale	2	
	26. Sandstone	34	
	27. Shale	1	
	28. Sandstone	3	
	29. Coal, Upper Freeport.		
	Total		645

This is in the same geological trough as the section at Ligonier (Fig. 36), and, as will be observed, agrees with it in having an unusually large interval between the Pittsburgh coal and the base of the Morgantown sandstone. It is possible that the Upper Mahoning sandstone should not include Nos. 17–20 at this locality.

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Section near Fairfax Knob, West Virginia.—About 50 miles east from Newburg we come to the North Potomac Coal Basin, the southward extension of the Cumberland or Georges Creek field of Maryland, and there, in the vicinity of Fairfax Knob, Tucker County, West Virginia, the Barrens exhibit the following structure (Fig. 45):

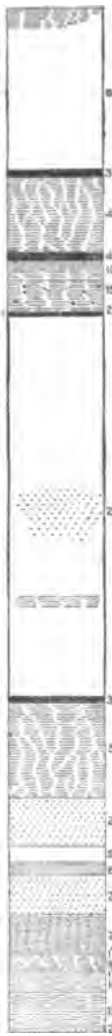

FIG. 45.—Section at Fairfax Knob, W. Va.

Fairfax Knob, Tucker County, West Virginia.

[See map, O o.]

		Ft.	Ft.	in.
	1. Pittsburgh coal			
	2. Shales and concealed		85	
	3. Coal, Little Pittsburgh: Coal 2′ 9″; Slate 0′ 0″; Coal 0′ 6″		3	9
	4. Shales		40	
	5. Coal: Coal, slaty 0′ 10″; Coal 1′ 8″; Slate 1′ 0″; Coal 1′ 0″		4	3
	6. Fire clay and shales		10	
	7. Blue shales with iron ore		15	
	8. Black slate		2	
	9. Coal, Little Clarksburg: Coal 0′ 8″; Slate 0′ 4″; Coal 1′ 0″		2	
	10. Concealed, with sandstones and shales		200	
	11. Coal, and black slate, Masontown		3	
	12. Shales		50	
Upper Mahoning.	13. Sandstone, massive	25		
	14. Concealed	9		
	15. Sandstone, soft	1	61	
	16. Clay, yellow	6		
	17. Sandstone	20		
	18. Limestone, Mahoning		20	
Lower Mahoning.	19. Soft shale	1		
	20. Hard shale	9		
	21. Soft shale	1		
	22. Slate, light blue	10	42	
	23. Slate, dark	19		
	24. Sandstone	2		
	25. Coal, Upper Freeport.			
	Total		538	

The last 100 feet of the section was obtained from the record of a diamond drill hole put down by the West Virginia Central Railroad to test the character of the Upper Freeport coal. The writer saw samples of the Mahoning limestone, taken from the drill hole, and it was a dark gray, rather pure limestone.

No. 5 is a second Little Pittsburgh coal which is occasionally present in the Potomac basin and elsewhere.

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Section in Guernsey County, Ohio.—Toward the northwestern side of the Appalachian basin, in Ohio, the Barrens are thinner than elsewhere, as may be seen from the following section (Fig. 46), made by Mr. F. W. Minshall, in Guernsey County, Ohio.

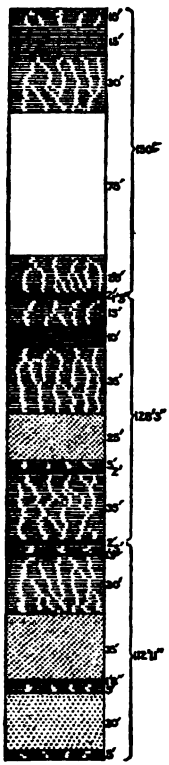

FIG. 46.—Section in Guernsey County, Ohio.

Guernsey County, Ohio.

[See map, H f.]

	Ft.	in.	Ft.	in.
1. Pittsburgh coal				
2. Shales	10			
3. Limestone	15			
4. Shales	30		150	
5. Concealed	75			
6. Shales	20			
7. Limestone, crinoidal			2	
8. Coal, crinoidal	1	3		
9. Shales	15			
10. Limestone	10			
11. Shales	35			
12. Sandstone, pebbly	25		128	3
13. Shales	5			
14. Coal, Bakerstown	2			
15. Shales	35			
16. Limestone, Lower Cambridge			2	
17. Shales	5			
18. Coal, Masontown	1	3		
19. Shales	30			
20. Sandstone, Upper Mahoning	35			
21. Coal, Mahoning	1	8	112	11
22. Shales	5			
23. Sandstone, Lower Mahoning	30			
24. Shales	5			
25. Coal, Upper Freeport.				
Total			395	2

Section at Burning Springs, West Virginia.—At Burning Springs, Wirt County, West Virginia, the Barren Measures have the following structure (Fig. 47), according to Mr. Minshall:

Burning Springs, Wirt County, West Virginia.

[See map, P g.]

	Ft.	in.	Ft.	in.
1. Pittsburgh coal				
2. Shales	10			
3. Limestone	10		200	
4. Concealed	180			
5. Limestone, crinoidal			3	
6. Coal, crinoidal	1	8		
7. Shales	10			
8. Limestone	3		294	8
9. Concealed	200			
10. Sandstone	40			
11. Shales	40			
12. Coal, Upper Freeport.				
Total			497	8

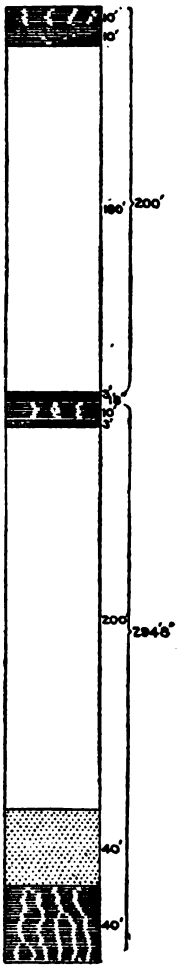

FIG. 47.—Section at Burning Springs, W. Va.

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Section near Huntington, West Virginia.—Near the southwestern limit of the district, in the vicinity of Huntington, West Virginia, the Barren Measures have the following structure (Fig. 48) according to the determinations of Mr. A. G. Selby, who made careful measurements of the rocks exposed there, and combined them with the record of a boring for gas:

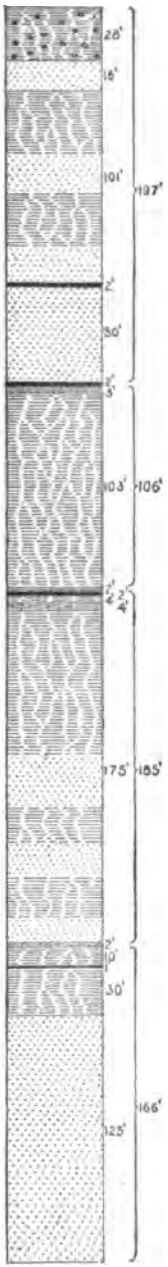

FIG. 48.—Section near Huntington, W. Va.

Vicinity of Huntington, West Virginia, along Ohio River.

[See map, S b.]

	Ft.	Ft.
1. Pittsburgh coal		
2. Red shale, containing limestone nodules	28	
3. Sandstone, shaly	16	
4. Red shales and shaly sandstone	101	197
5. Coal, Little Clarksburg	2	
6. Sandstone, massive, Morgantown	50	
7. Elk Lick coal		2
8. Fire clay	3	106
9. Shales, deep red	103	
10. Limestone, crinoidal		2
11. Coal, crinoidal	2	
12. Red shales	4	
13. Limestone	4	185
14. Shales and sandstones	175	
15. Limestone, Lower Cambridge		2
16. Shales	10	
17. Coal, Masontown	1	166
18. Shales	30	
19. Sandstone, Mahoning	125	
20. Upper Freeport coal.		
Total		600

This is nearly twice the thickness that the Ohio geologists report for the Barrens along the northwestern margin of their outcrop, but all of the measures thicken very rapidly toward the southeast from this portion of Ohio. It is possible, however, that Mr. Selby may have gotten some of the elements of the section too thick, since there is no single point between Huntington and the Big Sandy where a vertical measurement of all the members can be made. The true thickness can not be much under 600 feet at least.

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Section near Charleston, West Virginia.—In the vicinity of Charleston, West Virginia, and just north from it, the Barren Measures attain a greater thickness than anywhere else in the Appalachian Basin, so far as known. The following structure (Fig. 49) may be observed along the Great Kanawha River there, and its tributary, Two-mile Creek:

Near Charleston, West Virginia.

[See map, S f.]

	Ft.	Ft.
1. Pittsburgh coal		
2. Concealed red shales and sandstone	140	
3. Sandstone, massive	30	320
4. Red shales, sandstone and concealed	150	
5. Coal, Elk Lick		1
6. Shales	10	
7. Sandstone	30	70
8. Shales, marly, with limestone nodules	30	
9. Limestone, impure (crinoidal horizon)		5
10. Dark red shales with iron nodules	30	
11. Shales	25	
12. Coal, impure, Bakerstown	5	
13. Fire clay and shales	5	215
14. Sandstone, massive, pebbly	30	
15. Shales and sandstone	100	
16. Shales, with streaks of coal, Masontown	20	
17. Sandstone, very hard	25	
18. Coal, Mahoning	4	
19. Massive sandstone	75	
20. Shales	10	
21 Coal, Upper Cannelton	2	
22. Sandstone, massive	50	189
23. Sandy shales	15	
24. Coal, Middle Cannelton	1	
25. Black flint	5	
26. Shales	2	
27. Coal, Upper Freeport.		
Total		800

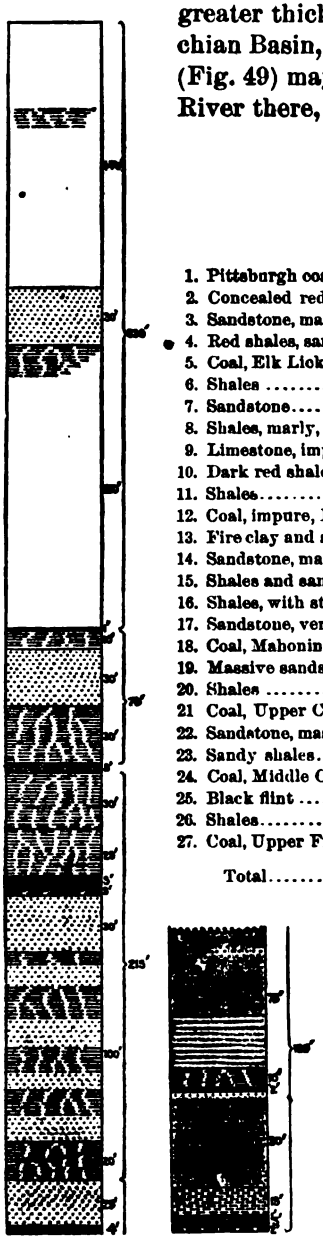

FIG. 49.—Section near Charleston, W. Va.

As may be seen from these sections just given, many of the beds which have received distinct names are not persistent. They occur at some localities but are wanting in others, and hence are so variable that they are never all found in one section.

We shall now take up the more important members of the series and describe them in more detail as exhibited at their type localities and elsewhere.

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CHARACTERISTIC HORIZONS.

THE PITTSBURGH COAL ORES.

In Fayette County, Pennsylvania, a group of iron ores come immediately below the Pittsburgh coal, and have been mined for the manufacture of iron for nearly 75 years. They have been very carefully studied by Stevenson, who describes them in his report (KK) of the Pennsylvania Geological Survey. He gives the following as the general section of the ores:

Pittsburgh coal	
Clay	2 to 8 feet.
Blue Lump ore	1 to 0 foot.
Clay	4 inches to 1 foot 6 inches.
Condemned flag ore	1 to 0 foot.
Clay	4 inches to 2 feet 6 inches.
Big Bottom ore	1 foot to 1 foot 8 inches.
Clay	10 inches to 5 feet.
Red flag ore	2 inches to 6 feet.
Clay	1 to 3 feet.
Yellow flag ore	4 inches.

This succession does not, of course, represent the structure of the ore layers at all localities, as the thickness and quality are constantly varying.

The "Blue Lump" and the "Big Bottom" beds are of the most importance, and it is from the former one especially that Mr. F. H. Oliphant manufactured iron so long and successfully at Fairchance. These ores are confined principally to the Blairsville basin, in Fayette County, though they extend into the edge of Monongalia County to the south, and have been recognized on the edge of Greene County to the west.

When these ores are not present their places are often occupied by ferruginous limestones or shales, though occasionally a sandstone stratum comes in close under the coal and cuts out everything else. This interval, immediately below the Pittsburgh, for 30 to 40 feet is more variable than any other portion of the Barrens, and hence it is useless to attempt to classify its rocks.

THE LITTLE PITTSBURGH COAL.

At a varying interval of 25 to 60 feet from the top of the Barrens there often occurs a thin and usually impure coal bed, which has been termed the Little Pittsburgh coal, from the fact that it is so close to the great bed above. The thickness seldom exceeds two feet, and it is often only half that. The best development of this coal which the writer has ever seen occurs in Fairfax Knob, Tucker County, West Virginia, at the locality of Section 45, where the bed is nearly 4 feet thick and is locally known as the "coking vein," from the fact that it has the typical structure of a good coking coal.

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Occasionally there appear to be two of these beds, one at 20 to 30 feet below the Pittsburgh and the other at 50 to 75 feet below, but they may probably both be splits from the same bed.

The Little Pittsburgh coal is quite persistent at the northern end of the Appalachian coal basin, but it disappears southwestward across West Virginia and is seldom seen beyond Harrison County. It also fades away southward in Ohio, since it does not appear in any of the Ohio sections, unless it should be the "Jeffers" coal of Prof. Andrews, in Gallia County. That, however, may possibly represent the Pittsburgh bed. In the vicinity of Wellersburg, Somerset County, Pennsylvania, there appear to be two of these Little Pittsburgh beds, and the upper contains 3 to 4 feet of good coal, while the lower is only 18 inches thick.

THE PITTSBURGH LIMESTONES.

There are very frequently two limestones in the shale interval of 50 to 75 feet below the Pittsburgh coal, one of which comes above the Little Pittsburgh coal and the other a few feet below. They are both known under the general name of Pittsburgh limestone; but it would be better to call the first one Upper Pittsburgh and the other one Lower Pittsburgh. The first is seldom more than 3 to 5 feet thick, but the latter is occasionally much thicker, as it is the more persistent of the two, being purer and frequently quarried and burned into lime for agricultural and other purposes.

THE CONNELLSVILLE SANDSTONE.

At a short interval under the Lower Pittsburgh limestone there is often found a massive sandstone which is frequently conglomeritic. This rock rises from the bed of the Youghiogheny River at Connellsville, and was named from that locality by Dr. Stevenson. Being one of the cliff rocks in the Barren Measures, it has played an important part in shaping their topography. It is especially hard and massive in the Cumberland or Georges Creek basin, and the rounded hills which hold the "Big" (Pittsburgh) "vein" rest on a platform of this rock, which, owing to its erosion-resisting power, makes a bold terrace far up the mountain sides after all the soft beds above have disappeared. It is this great bed of pebbly sandstone that caps the summits in the center of the trough south from Elk Garden, after the Pittsburgh coal has disappeared, forming almost level plateaus over thousands of acres where the great Pittsburgh bed is missed by an interval of only 50 to 60 feet.

The same pebbly sandstone marks the summits of the hills at Belington, Barbour County, West Virginia, and forms huge cliffs at many points along the Monongahela River between Fairmont and Morgantown.

At Connellsville the top of this stratum lies about 60 feet under the Pittsburgh coal; but this interval is sometimes as small as 40 feet, and

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again increases to 80 or 90. When not pebbly it frequently furnishes excellent building stone. The thickness varies from 25 to 50 feet, but it is often absent as a massive rock, and then its place is filled with sandy shales or flaggy sandstone.

THE LITTLE CLARKSBURG COAL.

By this name has been designated a bed of slaty coal which occasionally makes its appearance close under the Connellsville sandstone, and 100 to 125 feet below the Pittsburgh coal.

At Clarksburg, West Virginia, the coal in question crops out along the bed of Elk Creek for a considerable distance, and is 1½ to 2 feet thick, but poor and slaty. It is called Little Clarksburg to distinguish it from the Pittsburgh coal, which is extensively mined in the vicinity of that town, and is locally known as the Clarksburg bed.

Very frequently this coal is represented by a bed of black slate, which is filled with fish remains, teeth, scales, etc. The deposit in question is rarely more than 1½ to 2 feet thick, and is often absent altogether, so that it is of very little economic importance, though in the Wellersburg region of Somerset County, Pennsylvania, it attains a thickness of nearly 6 feet, and contains some good coal, being known as the "6-foot" bed.

THE CLARKSBURG LIMESTONE.

Directly under the last described coal there often occurs a limestone which is finely exposed in the vicinity of Clarksburg, along the bed of Elk and the West Fork River. The upper portion is there rather slaty, and filled with fossil ostracoids and fish remains. The next layers under this are very compact, and come out in peculiar rhomboidal blocks. This entire limestone series is 20 to 30 feet thick, and some of the layers are quite ferruginous, so much so that they were mined for ore many years ago at an old charcoal furnace on Elk. Some iron ore was also obtained near Clarksburg from the roof shales just above the Little Clarksburg coal, and used in this furnace. The Clarksburg limestone is rather widely distributed in Pennsylvania and northern West Virginia, and is frequently mined, since many of its layers furnish good lime for fertilizing and building purposes.

THE MORGANTOWN SANDSTONE.

At 25 to 40 feet under the Clarksburg limestone, and separated from it by soft shales, we find one of the great sandstone horizons of the Barren Measures. This rock was named by Dr. Stevenson from its fine exposure at Morgantown, West Virginia, where it has been extensively quarried and used in building the State University and other structures. At this typical locality the top of the stratum lies about 200 feet below the Pittsburgh coal, and the thickness of the sandstone is 25 feet. It is of a yellowish gray cast, of medium grain and hardness, and splits readily into blocks of any desirable size. Scattered

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through the rock are stains of peroxide of iron and also a considerable quantity of feldspar grains, which are generally decomposed, thus giving the surface of the stone a mealy look. In some of the crevices and cavities of the sandstone pure kaolin has accumulated from this source. The base of the sandstone is often conglomeritic and sometimes brecciated.

This is a quarry sandstone nearly everywhere that its outcrop extends. All along the Monongahela River it has been quarried and used in building the locks of the Slack Water Company. The stone dam, No. 9, was built of rock from this stratum. It is one of the most persistent members of the Barren Measures, and often makes high cliffs. It caps the hills in the vicinity of Grafton, West Virginia, where it is also quarried, and it makes a line of conspicuous bluffs from there to beyond Newburg, along Three Fork, and far up into Barbour County along the Valley River. Along the North Potomac River, in Mineral, Grant, and Garrett Counties, the same rock is found, and on the Great Kanawha, Guyandotte, Big Sandy, Big and Little Muskingum, and other tributaries of the Ohio, this bed is generally conspicuous. At Huntington, West Virginia, on the banks of the Ohio, it is 50 to 60 feet thick, while on Crooked Run, Monongalia County, near the Pennsylvania line, the stratum is 100 feet thick. It is the first oil rock on Dunkard Creek, and some of the wells produced largely from it. In the deep borings of Washington County, Pennsylvania, where it underlies the surface 500 to 1,000 feet, this stratum is 35 to 50 feet thick, and generally contains salt water.

THE ELK LICK COAL.

Immediately under the Morgantown sandstone, or separated from it by only a few feet of shale, there comes a coal of very wide distribution which occasionally attains workable dimensions.

This name was given the coal in question by the First Geological Survey of Pennsylvania, but the place of the bed in the series remained uncertain till Messrs. Platt, of the Second Survey, recently determined the matter finally by identifying the massive sandstone above it at the typical locality as the Morgantown.

This coal attains a thickness of 4 feet in Somerset County, Pennsylvania, and has there been mined to a considerable extent for local use.

In Westmoreland, Fayette, and Alleghany it seldom exceeds 2 feet, and is generally less, but quite persistent.

In Preston County, West Virginia, north from Cheat River, this bed has been mined to a considerable extent and is known as the "top vein." In the summits near Bruceton it is 4 feet thick and a rather good coal.

At Morgantown it is nearly 4 feet thick, but rather poor and slaty.

South from Monongalia County, it is occasionally seen, but is not so

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thick as at the northern end of the field. At Glenville, Gilmer County, it is in the bed of the Little Kanawha River, and 18 to 20 inches thick.

The same coal is also recognizable on the Big Kanawha, but is there quite thin. In the section (48) at Huntington, West Virginia, Mr. Selby finds this coal 2 feet thick but very slaty.

It is not often reported by the Ohio geologists, and hence may frequently be absent from the measures in that State.

THE ELK LICK LIMESTONE.

In sections 37 and 43, a limestone is seen at a short interval below the Elk Lick coal, and from its occurrence at this horizon in Somerset County, Pennsylvania, it has been termed the Elk Lick limestone by Mr. Franklin Platt, of the Second Geological Survey, Pennsylvania. The stratum in question occurs at 200 to 240 feet under the Pittsburgh coal, and is not always present.

As exhibited in Somerset County, Pennsylvania, this limestone is of a light gray color, and often tinged with buff, the same being true of it in Monongalia. Platt reports it as 12 feet thick in Somerset, but in Monongalia it is only about half that, and is not persistent.

THE CRINOIDAL LIMESTONE (GREEN FOSSILIFEROUS LIMESTONE, AMES LIMESTONE).

The next step downward in the rocks takes us to a very important horizon and one which marks a change from fresh or brackish water deposits to marine conditions, for here we get abundant marine fossils for the first time in descending the column of rocks.

The bed in which these fossils occur has received several names. The geologists of the First Geological Survey of Pennsylvania called it the Green Fossiliferous limestone, the Ohio Survey has termed it the Ames limestone, while the Second Geological Survey of Pennsylvania has termed it the Crinoidal limestone. This latter name is so well known now in geological literature that it is probably best to let it stand, though as a synonym and geographical designation the Ames limestone may be retained.

The character of this stratum and its fossils have been admirably worked out by Stevenson, who first showed its importance as a stratigraphical horizon. It comes almost exactly midway in the Barren series, and hence it is a constant datum from which the geologist can measure either upward or downward to identify the rocks.

When once thoroughly known it can not be confused with any other rock in these measures, since it is the highest bed that contains abundant Brachiopods and Lamellibranchs, and its lithology is distinctly different from anything else. Prof. Stevenson thus aptly describes its general features: "Dark bluish or greenish gray, tough, and breaks with a granular surface much resembling that of a coarse sandstone. * * *. In all cases it is fossiliferous and contains immense numbers of crinoidal stems and spines or plates."

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Its common fossils are: *Productus Nebrascensis*, *P. Prattenianus*, *P. longispinus*, *P. semi-reticulatus*, *Hemipronites crassus*, *Spirifera camerata*, *S. plano-convexa*, *Athyris subtilita*, *Lophophyllum proliferum*, *Zeacrinus mucrospinus*, together with the undetermined plates and stems of crinoids.

Throughout Pennsylvania this stratum comes about 275 to 300 feet below the Pittsburgh coal, and the same distance above the Upper Freeport, though occasionally this last interval is increased to 350 feet. The rock is rarely more than 2 feet thick, and often not so much, but is wonderfully persistent. Even when not present as limestone its horizon is almost invariably made known by the fossiliferous shales which accompany the bed.

Through Ohio this rock is almost continuously present from the point where it enters the State near Steubenville clear around to where it leaves it at the Kentucky line near Catlettsburg.

Opposite Steubenville the bed is 8 to 10 feet thick, but this is unusual, since it is only 1 to 3 feet at most points in Ohio.

The interval between this rock and the Pittsburgh coal decreases westward to 200 feet on the Ohio River at Wellsburg, and farther west in Ohio the interval still further declines to 140 feet, but where it leaves the State at the southwest it increases again and gets to be 300 feet opposite Huntington, West Virginia.

Through this latter State the limestone holds its place very regularly in the series from the Pennsylvania line southward into Harrison and Lewis Counties, and it is also present on the Volcano uplift at Burning Springs and other points, still holding its characteristic fossils. It disappears, however, in passing from this Little Kanawha region southward to the Big Kanawha, for when we come to this latter stream the fossiliferous limestone is gone, and its horizon replaced near Charleston by a thin, impure limestone which holds only minute fresh water forms. It is highly probable, however, that the crinoidal bed comes in again a few miles north from Charleston, since on the Big Sandy it was followed 20 to 25 miles above the mouth of that stream, and there it still retains its crinoidal phase, though getting very impure where last seen in that valley.

THE CRINOIDAL COAL.

Immediately under the last described limestone we very often find a thin coal bed, which seldom exceeds 18 inches in thickness, and hence is of very little economic importance. In Somerset County, Pennsylvania, Mr. Franklin Platt identified with this coal No. 8 of the Berlin (37) section, a very impure, slaty bed, occurring in several layers in the vicinity of Berlin, where it is altogether 7 feet thick, and locally known as the Platt coal. If this identification be correct, this is the greatest development the coal ever attains.

There is only one other locality besides the Berlin region where this coal has been mined to any considerable extent, and that is at

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Burning Springs, Wirt County, West Virginia. Here it was mined and used for fuel in drilling the numerous oil wells once put down there, and it is still taken out on a small scale for domestic purposes, though only 20 inches thick. Some very finely preserved fossil Brachiopods and Lamellibranchs have been obtained from the roof shales of the coal at Burning Springs, since it there comes only 2 to 5 feet below the Crinoidal limestone.

The "Weller" coal, near Wellersburg, Pennsylvania, is probably identical with this bed.

RED SHALE BEDS.

Throughout most of the Pennsylvania and West Virginia region, the Crinoidal limestone is underlaid by very soft, red, and variegated shales, and marly clays. They make a broad red band in the soil wherever they extend, and are a great nuisance along roads and railroads, since when wet they decompose into a greasy mud, which produces many landslides and slips.

It is this stratum which causes so much trouble to the oil and gas drillers of southwestern Pennsylvania and the adjoining regions of West Virginia, since it is so easily reduced to mud, which runs into the hole and fills it up, so that casing must be put through the stratum as soon as the drill has penetrated it. From this tendency to slide out into the drill hole, it is termed by the oil drillers the "caving" rock.

Over a large portion of Ohio and in many regions of West Virginia a hard, bluish gray limestone, not at all or but sparingly fossiliferous, occurs near the center of this shale interval. The bed is 3 to 10 feet thick, and in Ohio is generally called the Ewing limestone. It is shown in the West Virginia sections at Burning Springs (47) and at Huntington (48), and it is recognizable at many other points in the State.

The rest of the Barren Measures from this red shale down to the Mahoning sandstone is extremely variable. Sometimes it is nearly all shales, much of which is red, and "caves" in drilling through it, just like that under the Crinoidal limestone, and again as in the Berlin section (37) it contains 3 or 4 coal beds, and as many limestones. Some of these, however, are rather persistent and will be referred to in detail.

THE BAKERSTOWN COAL.

At some localities in western Pennsylvania a bed of coal is found 75 to 90 feet under the Crinoidal limestone. This bed is mined in the vicinity of Bakerstown, Alleghany County, and it has been designated from that village. As there exhibited, it is not quite 3 feet thick and rather slaty. In the Berlin region a coal called the Price bed seems to come at this horizon. It is about 4 feet thick and furnishes some valuable fuel in Somerset County.

In Section 37 will be found some thin coal beds under the Price coal, which are rarely represented in any other section of the Barrens.

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Among these are the Coleman, Philson, and the one a few feet under the Price bed; but they are all local, though occasionally we find traces of some of them in other regions than Somerset County. This whole interval for 100 feet below the Crinoidal limestone is so extremely variable that the classification for one region is of very little use in another. An instance of this is seen at Saltsburg, Pennsylvania, where a great sandstone 100 feet thick comes into the series a few feet under the Crinoidal limestone horizon. This was termed the Saltsburg sandstone by Stevenson, but it is hardly persistent enough to classify as a regular member of the Barrens. In the Charleston, West Virginia, region a massive pebbly sandstone occurs not far from the horizon of the Saltsburg rock, and the one which caps the hills at the mouth of the Big Sandy River may be identical with the same bed.

THE CAMBRIDGE LIMESTONES.

At many localities in Ohio two dark fossiliferous limestones occur only 20 to 30 feet apart, and Prof. Orton, director of the Ohio Geological Survey, has named them respectively the Upper and Lower Cambridge limestones. In Ohio these beds generally occur from 90 to 130 feet under the Crinoidal limestone and are always very fossiliferous.

In many regions of Pennsylvania two dark fossiliferous limestones occur, which correspond to the two in Ohio, only there they are 60 to 70 feet apart, and the upper one 90 to 120 feet under the crinoidal bed, while the lower one is 150 to 190 feet below the same horizon. I have identified the two in Pennsylvania with the two in Ohio, and have also adopted the Ohio names, since the Pennsylvania beds are known under several names in different parts of the field, while the Ohio names are now well established. The upper one is the lighter colored of the two, and while generally fossiliferous, the fossils are not so abundant as in the lower limestone. This upper one was termed the Pine Creek limestone in my Report Q of the Pennsylvania Survey, while in Somerset County it seems to be identical with the Coleman limestone of Platt.

At Morgantown, West Virginia (Section 42), this bed is dark, quite fossiliferous, and lies 85½ feet below the Crinoidal limestone.

The term Black Fossiliferous limestone of the First Pennsylvania Geological Survey Reports was probably applied quite as often to this upper rock as to the lower one, since at times they very closely resemble each other, and contain practically the same fossils.

The interval separating the two limestones is generally shale in Ohio, but in Pennsylvania it is sometimes a massive sandstone, and 60 to 90 feet thick.

The Lower Cambridge limestone is identical with the one termed Brush Creek limestone by the writer in Report Q, Second Geological Survey of Pennsylvania, but the geological horizon of that limestone was there placed lower than it should have been by 50 to 60 feet, since it was considered to belong between the two members of the Mahoning

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sandstone, instead of above both members, and hence the term Brush Creek limestone should be dropped from the nomenclature, and Lower Cambridge substituted. This lower limestone is very fossiliferous, often being a mere mass of Brachiopods and Lamellibranchs, of which the most common are *Chonetes mesoloba*, *Athyris subtilita*, *Pruductus Nebracensis* and a large Solenomya, together with *Nautilus occidentalis* and *Orthoceras cribrosum*.

This bed seems to be quite as persistent in Ohio as the Crinoidal limestone, since it is present in almost every section at the proper horizon, from Steubenville clear around to Ironton, near which latter point it is only 75 feet above the base of the Barrens.

In the hills at Catlettsburg, Kentucky, a dark fossiliferous limestone occurs at 160 feet above the Upper Freeport coal, but this is probably the Upper Cambridge, and the same limestone occurs in the summits of the hills opposite Louisa, Kentucky, at 200 feet above the Upper Freeport bed. It is barely possible, however, that this may be the Lower Cambridge limestone, since the Barrens thicken very rapidly southward from their northwestern outcrop. In the Berlin section, (37), the Lower Cambridge limstone appears to be represented by the Philson limestone of Platt. The "calcareo-siliceous rock" of Hildreth, in Ohio, appears to represent the same bed.

THE MASONTOWN COAL.

At an interval of 5 to 20 feet below the Lower Cambridge limestone there occurs a coal bed which has quite a wide distribution. It attains its best development in the region of Masontown, Preston County, West Virginia, and it has been designated from that village. It is there, and at many other points in the Preston basin, mined for domestic purposes, being known as the "4-foot" bed, and is a dry, open-burning coal, highly prized for domestic fuel. It is everywhere preferred to the Upper Freeport, which is accessible in the same region.

This appears to be the same bed which the writer described in Report Q, Second Geological Survey of Pennsylvania, under the name of Brush Creek coal, since a diamond drill hole has recently shown that the Brush Creek bed lies 135 feet above the Upper Freeport coal instead of 75, as formerly supposed, and hence it is deemed best to drop the name Brush Creek altogether for both the coal and the limestone. This Masontown coal is generally the first one above the top of the Mahoning sandstone, and the interval separating it from the latter varies from 5 to 50 feet. Very frequently the coal is only one-half to 1 foot thick, and sometimes it is represented only by black slate.

Near Gallitzin, Pennsylvania, it is seen in a cut on the old Portage Railroad, where it is only one-half foot thick, but it is overlaid by 3 to 4 feet of black slate. The coal is here 140 feet above the Upper

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Freeport coal as measured in the McCoy shaft, which starts at the horizon of the Masontown bed.

This coal is reported as present at many localities in Ohio, though there it seldom exceeds 2 feet in thickness. It is probably this bed which has been opened near the summit of the hill opposite Louisa, Kentucky, where it is 2 feet thick and rather slaty.

In the Belington basin, Barbour County, West Virginia, this coal attains a fine development and is often 4 to 5 feet thick with 6 inches of bony coal near the center.

THE IRONDALE LIMESTONE AND ORE.

Directly under the Masontown coal there is occasionally found a bed of buffish gray limestone, which at Irondale, Preston County, West Virginia, and adjoining regions, is accompanied by a bed of iron ore immediately under the limestone.

When the ore is present, however, the coal above is generally absent, as is the case at Irondale and Gladeville, Preston County, where the ore has been used to a considerable extent. It varies in thickness from 1 to 2 feet, and is rather siliceous, there being only about 38 per cent of metallic iron in the ore. It comes 155 feet above the Upper Freeport coal, and hence its horizon is assigned to that of the Masontown coal, since the interval agrees, and then a similar limestone 3 feet thick is seen under the coal at Albright and other localities in Preston County.

THE MAHONING SANDSTONE.

This is the lowest sandstone deposit of the Barren Measures, and although at times consisting of one solid rock, yet it is generally complex. The usual rule is for the mass to divide into two sandstones, an Upper and Lower Mahoning, each 40 to 50 feet thick, with a shale interval between containing a coal bed and limestone or iron ore, but sometimes when the group reaches a great development, as on the Big Kanawha (Section 49), it contains three coal beds, and as many sandstone divisions. This is exceptional, however, the normal structure having only two sandstones with one included coal, the whole series being 100 to 150 feet thick.

The wild scenery and poor soil of the lower portion of the Barrens are largely due to these sandstones. Being frequently quite hard and even pebbly, they cap the hills long after all the other members of the Barrens above have disappeared, and they have thus protected the underlying Lower Coal Measures over wide areas where the latter would otherwise have been carried away by erosion.

In Wyoming County, West Virginia, they cap the summits of Guyandotte Mountain at an elevation of 3,000 feet above the sea. Much of the Lower Coal Measures between that mountain and the Great Kanawha River would have been swept away but for this massive coping.

It is the same friendly cover that has preserved large areas of the

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Coal Measures on the summits of the Alleghany Mountains, and in isolated basins like Broad Top. The great tunnels on the Pennsylvania and Baltimore and Ohio Railroads, Gallitzin and Kingwood respectively, pass under domes of this sandstone group. Some portions of this sandstone nearly always furnish good building rock, the Government locks on the Great Kanawha being constructed of it. The same stone is also largely quarried along the Ohio River hills in Beaver County, Pennsylvania.

The Upper Mahoning is generally more massive than the Lower one, and is the conglomeritic member, since it is often a mere mass of quartz pebbles, having once been quarried for mill stones on Cheat River near Morgantown. In the Great Kanawha region this rock is extremely hard and siliceous, and at many points a mere bed of pebbles, some of which are as large as an egg.

THE MAHONING COAL.

This is the coal bed which is so often bound up between the two great divisions of the Mahoning sandstone. It was formerly called the Brush Creek by the writer, but as the place of that coal was misunderstood, it is thought best, as already stated, to drop the name entirely, and replace it with the name Mahoning, since it comes in the middle of the Mahoning sandstone. It is possible that the Gallitzin coal of Platt in Cambria and Blair Counties may belong at this horizon, but owing to the uncertainty connected therewith it has been deemed best not to adopt that name.

This is a very widely distributed coal bed, and frequently attains commercial importance. It is the coal No. 7 of the eastern Ohio series, where it is 3 feet thick and very excellent fuel. It is mined at many localities in Ohio, as well as in Pennsylvania.

On the Great Kanawha River, a few miles above Charleston, this bed swells out to a thickness of 17 feet in the vicinity of Coalburg; but much of this is slate and bone, there being only 5 to 6 feet of good coal in the bed. There is probably a considerable area of this coal of merchantable thickness in the region southwest from the Great Kanawha, since it is several feet thick along the summits of ridges in the Huff Creek Mountains, at the southern line of Logan County, and the same bed is 5 feet thick along the Tug branch of Big Sandy, and in the Peach Orchard region of Kentucky, where it occurs 235 feet above the Peach Orchard bed (Winnifrede). The coal is quite hard, and in many places a "block" coal through this southwestern region. The interval of this bed above the base of the Barren Measures varies from 50 to 175 feet, this latter being the figure at Coalburg and Peach Orchard.

THE MAHONING LIMESTONE.

Occasionally a limestone comes into the series immediately under the Mahoning coal. In Beaver County, Pennsylvania, it is often 5 to 8 feet

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thick, and is locally termed the "Summit" limestone. It is not a persistent bed, being much less so than the coal of the same name above, and when present it is often impure and ferruginous. In fact it is occasionally an iron ore, the Johnstown ore of Pennsylvania being identical with this stratum.

THE UPPER AND MIDDLE CANNELTON COALS.

Along the Great Kanawha, where all of the measures have thickened up so abnormally, two other coal beds make their appearance in the Barren series below the Mahoning coal, and they have been termed the Upper and Middle Cannelton, from a locality on the Kanawha where both are exposed. The former has there been mined for a long time in the summit of the hills, where it furnishes 5 feet of excellent "block" coal. It comes 90 feet above the base of the series, but the interval constantly decreases northward, and at Charleston is only 40 to 50 feet. As this interval decreases the coal becomes inferior, until at Charleston it is represented by some coaly streaks only, about the middle of the Lower Mahoning sandstone.

The Middle Cannelton coal never attains commercial value, and is found only in the region of Cannelton and southward. It is slaty, worthless, never more than 3 feet thick, and comes 20 to 25 feet above the base of the Barrens.

The Lower Mahoning sandstone is generally of a bluish gray color, quite homogeneous, and often an excellent building stone. Though occasionally containing pebbles, it is much freer from them than the Upper Mahoning. The thickness varies from 30 to 50 feet, except in the Kanawha region, where it splits up into two or three divisions, and is more than 100 feet thick.

The shales which separate the Upper and Lower Mahoning sandstones are sometimes red, or variegated, as in the Sewickley section (34); and, occasionally, as in the vicinity of Tunnelton, Preston County, West Virginia, good fire clay occurs at the horizon of the Mahoning limestone.

Both members of the Mahoning sandstone are occasionally oil-producing, but more generally the upper one, this being the main oil rock at Bobtown, on Dunkard Creek, Greene County, Pennsylvania, and on Whitely Creek. It is known to the oil producers as the "Dunkard sand," and it is also oil-bearing in the Macksburg and other regions of Ohio.

The shales which usually intervene between the base of the Mahoning sandstone and the Upper Freeport coal often contain fossil Brachiopods and Lamellibranchs, as well as the common coal measure plants. They are quite variable in thickness, the Lower Mahoning sometimes cutting out the shales entirely and resting on the Upper Freeport coal, while again the shales may thicken up to 50 feet.

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THE KANAWHA BLACK FLINT.

In the midst of the shales at the base of the Barrens, and apparently at the horizon which usually contains the marine fossils, there occurs along the Great Kanawha River a peculiar deposit, known locally as the "Black Flint." It makes its appearance in the section first at Charleston, and occurs from there southward along the river until the Barrens disappear from the summit of Gauley Mountain, 50 miles distant.

The distribution of the flint appears to be confined to a belt along the river 10 to 12 miles wide, since at 5 to 6 miles back on either side it generally disappears from the section, so as to be no longer recognizable. It is not confined to the Kanawha region however, since the deposit is visible near Clay Court House, on Elk River, and near the California House, on the crest of the Burning Springs anticlinal, where it crosses Hughes River at the corner of Wirt and Ritchie Counties. The rock varies from 5 to 15 feet in thickness, and is usually of a dark or bluish black color, though at the California House it is light colored. Being almost indestructible by atmospheric agencies, it has played a conspicuous part in shaping the topography in the Kanawha region, since it protects the underlying beds from erosion. Through the agency of heat and cold it finally breaks down into oblong and rudely rectangular blocks which everywhere line the beds of streams and cover the surface below the line of outcrop. The Indians manufactured arrow heads and other implements from this material, so that pieces of it have been found as far north as Pennsylvania. It is evidently a marine deposit, since it is distinctly stratified, and specimens of *Discina*, *Spirifera*, and *Productus* are common in the less siliceous layers. The flint is evidently derived from the skeletons of diatoms and protozoa, though no microscopic examination has been made.

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CHAPTER V.

THE LOWER COAL MEASURES, OR ALLEGHANY RIVER SERIES.

THICKNESS, CHARACTER, AND EXTENT.

Below the Barren Measures or Elk River series there occurs a group of rocks (No. XIII) which always holds valuable coal beds. From the fact that they are finely exposed along the Alleghany River, they were long ago called the Alleghany River series, and their geological position in the general scale of the Carboniferous gave them the name Lower Coal Measures. The discovery in recent years that the next lower group of beds (the Pottsville Conglomerate) sometimes holds workable coal, has been used as an argument by some geologists for breaking up the old nomenclature and rearranging the Carboniferous into new groups, but this nomenclature is so convenient, and expresses the natural divisions of the rocks so well, that it would be very unwise to make any such changes as have been proposed, since it would be of no particular service and would only bring confusion to the minds of many people interested in Carboniferous geology who are now thoroughly conversant with the old and tried nomenclature of Pennsylvania and Virginia. Hence, while for strictly scientific purposes it may be well to group the Carboniferous rocks on a wider basis as proposed in a former part of this report, yet for every day field work in practical geology, the old nomenclature can not be improved upon.

The Lower Coal Measures, as now limited, begin at the top with the widely distributed and valuable Upper Freeport coal bed (a horizon which is easily recognized anywhere by the field geologist) and extend down through several beds of shale, limestone, coal, and sandstone till a horizon is reached where a marked change in lithology takes place, the sandrocks becoming harder, more massive, and often pebbly, accompanied with a corresponding change in the character of the imbedded fossils.

The thickness of this series varies greatly in different portions of the field, being not far from 300 feet in western Pennsylvania, and seldom less than 250 feet anywhere in that State, except in the Broad Top field. But westward through Ohio the thickness of these measures declines until around the northwestern border of the field it is less than 200 feet. Southward from this region of Ohio, where the Lower Coal Measures are thinnest, they thicken up rapidly until on the Great Kanawha River the series is 1,000 feet thick, and the same on the Guyan-

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dotte and Tug Rivers. Just where this great thickening up begins in going southwestward from the Pennsylvania line is not exactly known, but there are good reasons for believing that much the greater portion of it takes place beyond the Little Kanawha River.

The topography made by these rocks is generally very much the same, except where the thickness is very great. It is nearly everywhere characterized by a hilly country, terraced with a series of parallel benches which, as Lesley long ago showed, mark the outcrops of the several coal beds, since the soft rocks usually found with every coal are more rapidly eroded than the harder ones above or below. These coal benches are not confined to the topography of the Lower Coal Measures, since they are due to a general law of erosion, but are only more conspicuous in this series because the coal beds are more numerous and closer together.

Through Pennsylvania, Ohio, and the northern half of West Virginia, with few exceptions, the hill slopes of these measures, while often rather steep, are not too rugged for good arable and grazing lands, and the soils are usually rich; but in the southwestern part of West Virginia, where these rocks have increased in thickness so largely, we find a network of narrow ridges, generally capped with the Mahoning sandstone, from which the surface falls away at an angle of 25° to 40° to the beds of the streams, 1,000 or more feet below, thus practically confining the arable land to the narrow valleys, which are frequently trenched into the top members of the next underlying or Pottsville series of rocks.

It was formerly supposed that this series held valuable coal only in a broad belt around the margins of the coal field, and that in the center of the Appalachian basin, where these beds are buried under 1,500 to 2,000 feet of superincumbent strata, they contained no coals thick enough to mine; but the recent drilling of many oil and gas wells over the central portion of the field has proved the supposition to be unfounded, for the drill has many times penetrated thick beds of coal in this series at localities where they underlie the surface by an interval of more than 1,500 feet. Hence, aside from local irregularities always to be found in any coal field, there is no reason for believing that the Lower Coal Measures do not contain one or more good coal beds under nearly every portion of the Appalachian field, and where it would seem to be otherwise the inference has been founded largely on defective records of borings, in which no attention was given to the character of the beds encountered unless they proved to be "sands." But while it is true that recent drilling has shown valuable coal in this series along the central portion of the trough where it was formerly supposed to be absent, yet it is true as a general law that the coal beds of this series are thicker and better and more numerous around the margins of the Appalachian field than toward the center. This is illustrated by the

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LOWER COAL MEASURES, COALBURG, KANAWHA RIVER, WEST VIRGINIA.

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distribution of the Clarion and Brookville beds, which are valuable only around the margin of the coal area.

Owing to the geological position of the Lower Coal Measures, their beds have a much wider spread and are accessible over a larger area than those in the Upper Coal Measures, so that when in the distant future the upper coals and the easily accessible areas of the lower ones shall have been exhausted, there will still remain far down in the trough of the Appalachian field a great wealth of fuel which can be obtained by deep shafting. It is true that at many localities disclosed by the drill only one good bed of coal has been found in this series where it lies so deep beneath the surface, but that is also true of the surface outcrops, and many places can be found where not even one good coal bed occurs in the surface section, and many others where two are the exception.

The main strata of this series, which have been recognized and traced over a wide area in the three States with which this report deals, have received the following names in descending order:

Upper Freeport coal.	Lower Kittanning coal.
Upper Freeport limestone.	Lower Kittanning fire clay.
Upper Freeport sandstone.	Lower Kittanning sandstone.
Lower Freeport coal.	Buhrstone iron ore.
Lower Freeport limestone.	Ferriferous limestone.
Lower Freeport sandstone.	Putnam Hill limestone.
Upper Kittanning coal.	Clarion coal.
Johnstown (Cement) limestone.	Brookville coal.
Middle Kittanning coal.	

Other beds have been named in this series which have a local distribution, but those given above are the main ones which can be traced and identified over wide areas.

Prof. Orton, director of the Ohio Geological Survey, has shown that all of the main beds of the Pennsylvania Lower Coal Measures can be followed and identified entirely across the Ohio coal field to where they enter Kentucky; and the writer has recently shown (The Virginias, 1885) that they also stretch unbroken around the southeastern margin of the Appalachian field, from the Pennsylvania line down through West Virginia to the Great Kanawha, and on across the Guyandotte to the Big Sandy, so that the identifications of the main beds of coal, limestone, and sandstone of the Lower Coal Measures have now been carried from Pennsylvania to the Kentucky line, on both sides of the Appalachian field.

As illustrations of these measures, in most of the important coal regions of the area in question, we shall now present a number of vertical sections. The identifications of the several beds in these sections have been made with all the care and light at present attainable, and while it is not claimed that they are final in all cases and free from error, yet they express the best efforts of the writer, and it is confidently believed

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that their publication will serve to stimulate a more careful study of the general stratigraphy by field geologists and those interested in mining enterprises, so that finally whatever of error may be embodied in these identifications will be discovered and eliminated. It is certain that the first effort to harmonize the stratigraphy over such a large area will be somewhat provisional, and hence the writer not only expects, but welcomes, the kindly criticism of his brother geologists, knowing that all will be pleased when the true order and succession of these beds are definitely determined in the several important regions of the Appalachian field.

In some cases, like that at Blossburg, where it has been impossible to identify the main coal beds with any degree of certainty, the writer has given only the local names for the beds, leaving the reader to draw his own conclusions from the general structure of the section; but there are very few cases where some one of the seams in a given section can not be reasonably determined.

We shall begin these illustrations of the Lower Coal Measures at the most northern point of the Appalachian Basin, and proceed southwestward through the field.

Section at Blossburg, Pennsylvania.—The structure of the Lower Coal Measures at the northern end of the Appalachian basin is given as follows (Fig. 50) for the Blossburg region, Tioga County, Pennsylvania, by the First Geological Survey of Pennsylvania, Final Report, Vol. II, page 520:

Blossburg, Tioga County, Pennsylvania.

[See map, B w.]

		Ft.	in.	Ft.	in.
1.	Coal, "Rock vein"			3	6
2.	Concealed			22	
3.	Coal, "Seymour"			5	
4.	Slate and sandstone	10			
5.	Concealed	10		47	10
6.	Sandstone, pebbly, with thin coal near top	27	10		
7.	Coal, "Dirty vein"			3	6
8.	Slate and sandstone			30	
9.	Coal			1	6
10.	Fire clay			3	
11.	Slate			20	
12.	Coal, "Bloss vein". { Coal 3′ 6″; Fire clay 5′ 0″; Coal 2′ 0″ }			10	6
13.	Argillaceous sandstone, with two thin coals			13	6
14.	Coal, "Bear Creek"			3	6
15.	Sandstone.				
	Total			163	10

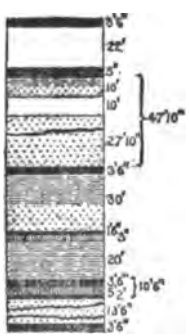

FIG. 50.—Section at Blossburg, Pa.

The "Bloss vein" seems to be identical with the Lower Kittanning bed of the Alleghany River, while the "Rock vein" and "Seymour" are possibly identical with the Upper and Lower Freeport beds, respectively. This would make Nos. 7 and 9 the Upper and Middle Kittanning.

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Section at Fall Brook, Pennsylvania.—At Fall Brook, 8 miles northeast from Blossburg, and the most northern development in the Appalachian coal field, the structure of the Lower Coal Measures is given as follows (Fig. 51) by Mr. Franklin Platt, in Report G, pages 166, 169, Second Geological Survey of Pennsylvania:

Fall Brook, Tioga County, Pennsylvania.

[See map, B x.]

		Ft.	in.
1. Coal, "Seymour"		2	6
2. Rough, sandy fire clay		2	
3. Sandstone, massive, pebbly		50	
4. Coal	Coal 1′ 8″; Sandstone, thin bedded 3′ 0″; Coal 0′ 7″	5	3
5. Fire clay		1	6
6. Sandstone		10	
7. Slate			9
8. Coal, "Dirty vein"	Coal 1′ 2″; Slate 4′ 0″; Coal 1′ 2″; Slate 0′ 3″; Coal 0′ 10″	7	6
9. Rough, hard fire clay		2	
10. Gray shaly rock		20	
11. Fire clay, with kidney ore at bottom		2	
12. Sandstone, light gray		9	
13. Clay slate		5	
14. Coal, "Bless vein"		4	
15. Fire clay, pure		3	
16. Sandy slate, some sandy layers		16	
17. Coal and slate, "Bear Creek"		1	6
18. Sandy clay		4	
19. Sandstone.			
Total		146	

FIG. 51.—Section at Fall Brook, Pa.

Section near Karthaus, Pennsylvania.—About 65 miles southwest of Blossburg, in the northeastern corner of Clearfield County, Pennsylvania, the following section (Fig. 52) of the Lower Coal Measures is reported from the vicinity of Karthaus, by H. D. Rogers, in the First Geological Survey of Pennsylvania:

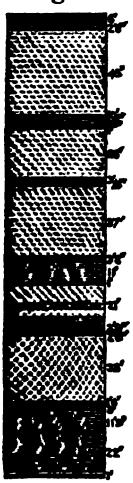

FIG. 52.—Section near Karthaus, Pa.

Karthaus, Clearfield County, Pennsylvania.

[See map, E t.]

		Ft.	in.
1. Coal, Upper Freeport		6	
2. Fire clay		2	6
3. Sandstone, brown		45	
4. Coal		0	10
5. Fire clay		2	
6. Limestone, siliceous		3	6
7. Shale		1	
8. Sandstone, brown		26	
9. Coal, Lower Freeport		3	
10. Slate		1	6
11. Sandstone, gray, Freeport		37	
12. Coal, Upper Kittanning		3	2
13. Shale, containing iron ore		11	
14. Coal, Middle Kittanning		1	
15. Sandstone and slate		21	
16. Coal, Lower Kittanning	Coal 1′ 0″; Slate 0′ 3″; Coal 2′ 6″	3	9
17. Fire clay		2	6
18. Sandstone, brown		35	
19. Coal, Clarion		1	6
20. Fire clay, ferruginous		3	
21. Shales, containing iron ore band		11	3
22. Shales and slates		22	
23. Coal, Brookville		1	
24. No. XII Conglomerate.			
Total		245	

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Section in Horton Township, Elk County, Pennsylvania.—Horton Township, Elk County, Pennsylvania, lies on the borders of Clearfield and Jefferson Counties, 30 miles west from Karthaus and about 80 miles distant west-southwest from the Blossburg region. In this township Mr. C. A. Ashburner finds the following section (Fig. 53) for the Lower Coal Measures, Report RR, page 227:

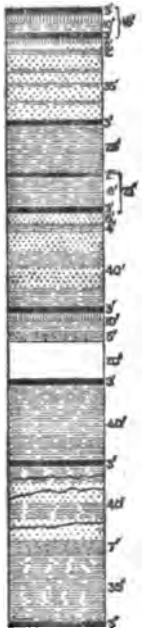

FIG. 53.—Section in Elk County, Pa.

Horton Township, Elk County, Pennsylvania.

[See map, D q.]

		Feet
1.	Coal, Upper Freeport: Coal 3′; Fire clay and shale 10′; Coal 3′	16
2.	Fire clay and sandstone	6
3.	Limestone, Upper Freeport	[illegible]
4.	Slaty sandstone	15
5.	Coal, Middle Freeport	[illegible]
6.	Soft gray slates	12
7.	Coal, Lower Freeport: Cannel 2′; Slate 16′; Coal 3′	21
8.	Sandstone	6
9.	Limestone, Lower Freeport	4
10.	Flaggy sandstone and slates	40
11.	Coal, Upper Kittanning	[illegible]
12.	Fire clay and slate	10
13.	Limestone, Johnstown Cement	5
14.	Concealed	20
15.	Coal, Middle Kittanning	[illegible]
16.	Black slate	40
17.	Coal, Lower Kittanning	[illegible]
18.	Shale and sandstone, occasional coal streak	40
19.	Limestone, Ferriferous	[illegible]
20.	Shale and slate	[illegible]
21.	Coal, Clarion	[illegible]
22.	Massive sandstone, top of XII.	
	Total	327

Section near Brockwayville, Pennsylvania.—Snyder Township, Jefferson County, adjoins Horton, and there, near Brockwayville, Mr. Wm. G. Platt reports the following structure (Fig. 54) for the Lower Coal Measures, Report H[6], pages 186, 187:

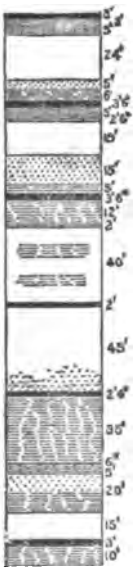

FIG. 54.—Section near Brockwayville, Pa.

Brockwayville, Jefferson County, Pennsylvania.

[See map, D q.]

		Ft.	in.
1.	Coal, Upper Freeport	3	
2.	Clay, impure	3	
3.	Limestone, Upper Freeport	5	
4.	Concealed	24	
5.	Sandstone, thin-bedded	5	
6.	Shales and slates	6	
7.	Coal, Lower Freeport	3	6
8.	Clay, impure	5	
9.	Limestone, Lower Freeport	2	6
10.	Concealed	18	
12.	Sandstone	15	
13.	Slates	5	
14.	Coal, Upper Kittanning	3	6
15.	Clay shales	13	
16.	Limestone, Johnstown Cement	2	
17.	Concealed, shales (?)	40	
18.	Coal, Middle Kittanning	2	
19.	Concealed, sandstone at base	45	
20.	Coal, Lower Kittanning	2	6
21.	Shales	35	
22.	Iron ore, Buhrstone		6
23.	Limestone, Ferriferous	5	
24.	Sandstone and shales	20	
25.	Concealed	15	
26.	Coal, Clarion	3	
27.	Shales	10	
28.	Sandstone, massive, top of XII.		
	Total	290	6

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Section in Clarion County, Pennsylvania.—Clarion County lies next west from Jefferson, and Mr. H. Martyn Chance gives in Report VV, page 32, Second Geological Survey of Pennsylvania, the following as the general structure of the Lower Coal Measures in that county (Fig. 55):

FIG. 55.—Section in Clarion Co., Pa.

Clarion County, Pennsylvania.

[See map, E o.]

		Ft.
1.	Coal, Upper Freeport	4
2.	Fire clay	5
3.	Limestone, Upper Freeport	3
4.	Shale, with ore	8
5.	Sandstone	25
6.	Shale	4
7.	Coal, Lower Freeport	6
8.	Fire clay	2
9.	Limestone, Lower Freeport	3
10.	Sandstone and shales	75
11.	Shale	10
12.	Coal, Upper Kittanning	2
13.	Fire clay or shale	3
14.	Limestone, Johnstown Cement bed	2
15.	Shaly measures	40
16.	Coal, Middle Kittanning	2
17.	Fire clay	2
18.	Shale and sandstone	30
19.	Coal, Lower Kittanning	4
20.	Sandstone and shale, with ore	25
21.	Ore, Buhrstone	1
22.	Limestone, Ferriferous	8
23.	Shale	7
24.	Clarion coal { Coal 2′; Slaty shale 25′; Coal 3′ }	30
25.	Fire clay	2
26.	Shale and sandstone	27
27.	Coal, Brookville	2
28.	Fire clay	3
29.	Massive sandstone, XII.	
	Total	335

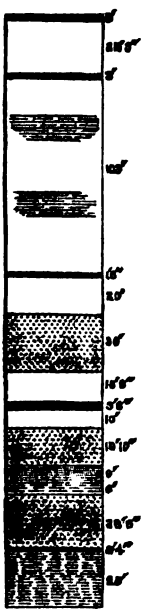

FIG. 56.—Section at Miller's Eddy, Pa.

Section at Miller's Eddy, Clarion County, Pennsylvania.—The following section (Fig. 56), made by Mr. John Haggerty, M. E., of Brady's Bend, Pennsylvania, represents the Lower Coal Measure structure at Miller's Eddy, near the mouth of the Clarion River (VV, p. 123):

Miller's Eddy, Clarion County, Pennsylvania.

[See map, E n.]

		Ft.	in.
1.	Coal, Upper Freeport	3	
2.	Interval	28	3
3.	Iron ore	2	
4.	Concealed and slate	103	
5.	Coal, Upper Kittanning	1	6
6.	Interval	20	
7.	Sandstone	30	
8.	Interval	16	6
9.	Coal, Lower Kittanning	3	6
10.	Interval	10	
11.	Sandstone	19	10
12.	Limestone, Ferriferous	9	
13.	Shales	6	
14.	Sandstone	28	6
15.	Coal, Clarion	2	4
16.	Blue shales	29	
17.	Sandstone, massive.		
	Total	312	5

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Section at East Brady, Clarion County, Pennsylvania.—Mr. Haggerty also leveled another section of these measures at East Brady, in the southwestern corner of Clarion County, which is given as follows (Fig. 57) in Report VV, p. 77:

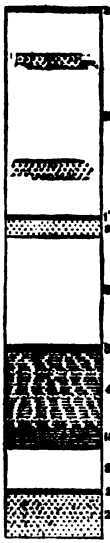

FIG. 57.—Section at East Brady, Pa.

East Brady, Clarion County, Pennsylvania.

[See map, F n.]

	Ft.	in.
1. Coal. Upper Freeport	2	
2. Concealed and sandstone	108	
3. Coal, Upper Kittanning	1	5
4. Sandstone	9	
5. Interval	57	6
6. Coal, Lower Kittanning	3	6
7. Shale, with sandstone	40	6
8. Limestone, Ferriferous	10	
9. Interval	22	2
10. Coal, Clarion	2	2
11. Sandstone	23	
12. Coal, thin, Brookville.		
13. Sandstone, No. XII.		
Total	279	3

Section near New Bethlehem, Pennsylvania.—Mr. Chance gives the following (Fig. 58) as the structure of the Lower Coal Measures in the vicinity of New Bethlehem, on the Red Bank River, in southeastern Clarion County, VV, p. 88:

FIG. 58.—Section near New Bethlehem, Pa.

Near New Bethlehem, Clarion County, Pennsylvania.

[See map, F o.]

	Ft.
1. Coal, Upper Freeport	5
2. Fire clay	3
3. Sandy shale and sandstone	42
4. Coal, Lower Freeport	7
5. Fire clay	3
6. Concealed, sandstone, and shale	65
7. Coal, Upper Kittanning	3
8. Fire clay	4
9. Shale	43
10. Coal, Middle Kittanning (?)	2
11. Fire clay	3
12. Concealed	60
13. Ore, Buhrstone	1
14. Limestone, Ferriferous	4
15. Concealed	50
16. Sandstone, top of XII.	
Total	285

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Section in Brady Township, Butler County, Pennsylvania.—In the northwestern portion of Butler County (Brady Township), Mr. Chance gives, in Report V, the following section (Fig. 59) for the Lower Coal Measures down to and including the Ferriferous limestone, and the portion below that is added from an exposure in an adjoining township:

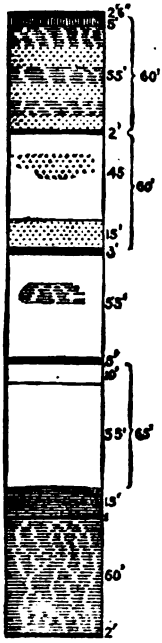

FIG. 59.—Section in Butler County, Pa.

Brady Township, Butler County.

[See map, F l.]	Ft.	Ft.	in.
1. Coal, Upper Freeport		2	6
2. Fire clay	5	60	
3. Shale and sandstone	55		
4. Coal, Lower Freeport		2	
5. Concealed, and massive sandstone	45	60	
6. Massive sandstone	15		
7. Coal, Upper Kittanning		3	
8. Concealed, and shale		55	
9. Coal, Middle Kittanning (?)		3	
10. Concealed	10	65	
11. Iron ore	thin		
12. Concealed	55		
13. Limestone, Ferriferous		15	
14. Coal, Scrubgrass		1	
15. Shales		60	
16. Coal, Brookville		2	
Total		328	6

Section near Ore Hill Furnace, Armstrong County, Pennsylvania.—In the vicinity of Ore Hill Furnace, Armstrong County, Pennsylvania, 3 miles below the mouth of the Mahoning River, the writer found the following succession (Fig. 60):

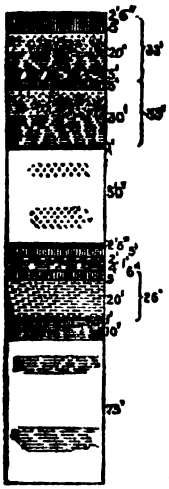

FIG. 60.—Section near Ore Hill Furnace, Armstrong County, Pa.

Ore Hill Furnace, Armstrong County, Pennsylvania.

[See map, G o.]	Ft.	Ft.	in.
1. Coal, Upper Freeport		2	6
2. Fire clay with iron ore	8	33	
3. Flaggy sandstone and shales	20		
4. Bituminous shales	5		
5. Coal, blossom, Lower Freeport			
6. Fire clay and limestones, Lower Freeport	5	35	
7. Flaggy sandstone and dark shales	30		
8. Limestone, gray, Johnstown Cement		1	
9. Concealed and sandstone		50	
10. Coal, Middle Kittanning		2	6
11. Fire clay		5	
12. Sandy shale		2	
13. Coal, Lower Kittanning { Coal 1′ 0″; Shale 4′ 0″; Coal 0′ 6″ }		5	6
14. Fire clay	5	26	
15. Shales, brown, sandy	20		
16. Iron ore, Buhrstone	1		
17. Limestone, Ferriferous		10	
18. Concealed and shales to top of No. XII sandstone in Alleghany River		75	
Total		247	6

This section exhibits a rapid thinning away of the whole column, but principally in that part of it between the Upper Freeport and the Upper Kittanning coals.

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Section near Centerville, Pennsylvania.—Five miles northeast from Ore Hill Furnace, the following succession (Fig. 61) is reported from the vicinity of Centerville by Mr. Wm. G. Platt, in Report H[5], Second Geological Survey of Pennsylvania, pages 163, 164.

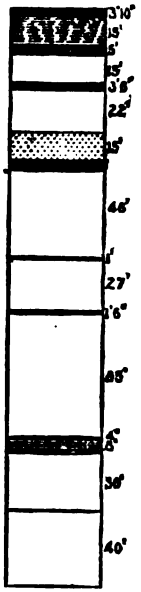

FIG. 61.—Section near Centerville, Pa.

Centerville, Armstrong County, Pennsylvania.

[See map, G o.]

		Ft.	Ft.	in.
1.	Coal, Upper Freeport		3	10
2.	Clay shales, with iron ore	15	35	
3.	Limestone, Freeport	5		
4.	Concealed	15		
5.	Coal, Lower Freeport		3	6
6.	Concealed	22	37	
7.	Iron ore, siliceous			
8.	Sandstone	15		
9.	Coal, blossom			
10.	Concealed		46	
11.	Coal, Upper Kittanning		1	
12.	Concealed		27	
13.	Coal, Middle Kittanning		1	6
14.	Concealed		65	
15.	Iron ore, Buhrstone		0	4
16.	Limestone, Ferriferous		8	
17.	Concealed		30	
18.	Cannel slate (Clarion coal)			
19.	Concealed		40	
20.	Black slate (Brookville coal).			
21.	Top of No. XII conglomerate.			
	Total		298	2

Section at Putneyville, Pennsylvania.—Five miles east of Centerville is the village of Putneyville, and from this vicinity Mr. Wm. G. Platt reports the following section (Fig. 62) of the series H[5], p. 150:

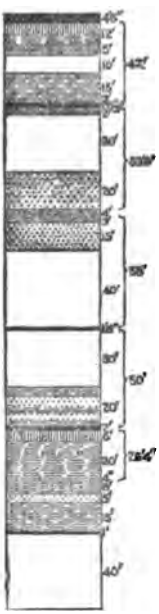

FIG. 62.—Section at Putneyville, Pa.

Putneyville, Armstrong County, Pennsylvania.

[See map, G o.]

		Ft.	in.	Ft.	in.
1.	Coal, Upper Freeport			4	6
2.	Fire clay and clay shales	12		42	
3.	Limestone, Upper Freeport	5			
4.	Concealed	10			
5.	Clay slates	15			
6.	Coal, Lower Freeport			3	
7.	Slate	1	6	53	9
8.	Iron ore	0	3		
9.	Limestone, Lower Freeport	2			
10.	Concealed	30			
11.	Sandstone	20			
12.	Coal, blossom, Upper Kittanning				
13.	Limestone, Johnstown Cement bed			4	
14.	Clay	3		58	
15.	Sandstone, friable	15			
16.	Concealed	40			
17.	Coal, Middle Kittanning			1	8
18.	Concealed	30		50	
19.	Slates, with sandstone layers	20			
20.	Coal, Lower Kittanning			2	
21.	Fire clay, impure	6		26	4
22.	Shales	20			
23.	Iron ore, Buhrstone	0	4		
24.	Limestone, Ferriferous			8	
25.	Sandstone, flaggy			5	
26.	Black slates			15	
27.	Cannel slate (Clarion coal)			1	
28.	Concealed			40	
29.	Brookville coal.				
30.	Top of No. XII, conglomerate.				
	Total			314	3

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Section near Kittanning, Pennsylvania.—In the vicinity of Kittanning, Pennsylvania, the succession of the Lower Coal Measures is as follows (Fig. 63):

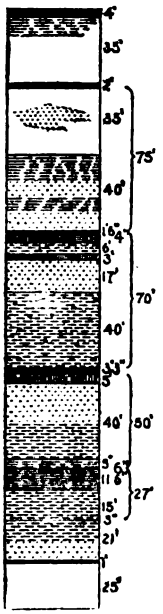

FIG. 63.—Section near Kittanning, Pa.

Vicinity of Kittanning, Pennsylvania.

[See map, G n.]

	Ft.	in.	Ft.	in.
1. Coal, Upper Freeport			4	
2. Shales, and concealed			35	
3. Coal, Lower Freeport			2	
4. Concealed, and massive sandstone	35			
5. Shales and sandstone	40		75	
6. Coal, slate in center, Middle Kittanning			1	6
7. Fire clay	4			
8. Sandy shales	6			
9. Fire clay	3		70	
10. Flaggy sandstone	17			
11. Shales, dark, sandy, with iron ore	40			
12. Coal, Lower Kittanning: Coal 1′ 10″; Slate 0′ 2″; Coal 0′ 8″; Bone 0′ 1″; Coal 0′ 6″			3	3
13. Fire clay	5			
14. Sandstone and sandy shales	40		50	
15. Shales, with iron ore	5			
16. Iron ore, Buhrstone	0	6		
17. Limestone, Ferriferous	11	6	27	
18. Sandy shales	15			
19. Coal			0	3
20. Sandy shales and sandstone			21	
21. Coal, Clarion			1	
22. Concealed, to top of No. XII sandstone			25	
Total			315	

Section 5 miles south of Kittanning, Pennsylvania.—About 5 miles south of Kittanning and 1 mile below the mouth of Crooked Creek a very important exposure may be seen on the left bluff of the Allegheny River, since it gives in a clear manner the relations of the upper members of the Lower Coal Measures. The section there (Fig. 64) was carefully leveled by the writer, and reads as follows:

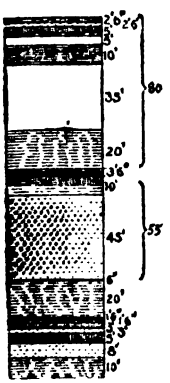

FIG. 64.—Section south of Kittanning, Pa.

Five miles below Kittanning.

[See map, G n.]

	Ft.	in.	Ft.	in.
1. Coal, Upper Freeport, blossom				
2. Fire clay	2	6		
3. Sandstone	2	6		
4. Fire clay and shales	5			
5. Concealed	5		80	
6. Limestone, Upper Freeport	10			
7. Concealed	35			
8. Shales, bluish	20			
9. Coal, Lower Freeport: Coal 0′ 2″; Slate 1′ 8″; Coal 1′ 8″			3	6
10. Fire clay and shales	10		55	
11. Sandstone, massive, pebbly, Freeport	45			
12. Coal, Upper Kittanning			0	6
13. Shales, dark			20	
14. Coal, slate in center, Middle Kittanning			1	6
15. Limestone, sandy			1	6
16. Fire clay			3	
17. Sandstone, flaggy			3	
18. Fire clay			5	
19. Sandstone, flaggy			8	
20. Shales, dark			10	
Total			191	

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Section at Logansport, Pennsylvania.—The last section gets its special significance when compared with another one, obtained 2 miles below, on the right bank of the Alleghany River, and opposite the town of Logansport. The section there (Fig. 65) gives the following structure:

Logansport, Armstrong County, Pennsylvania.

[See map, G n.]

		Ft.	Ft.	in.
1. Coal, Upper Freeport			3	
2. Fire clay		4		
3. Limestone, Upper Freeport	Impure limestone 2′; Limy shales 4′; Limestone, good 1′; Shales 1′; Limestone, "glassy layer" 2′; Limy shales 2′; Limestone, good 2′	14	28	
4. Shales and fire clay		10		
5. Coal, Lower Freeport	Coal 2′ 0″; Fire clay, impure 2′ 4″; Coal 4′ 8″		9	
6. Concealed		11	81	
7. Very massive, grayish white, pebbly sandstone, Freeport		70		
8. Coal, Upper Kittanning			0	8
9. Dark gray shales			20	
10. Coal, Middle Kittanning	Coal 0′ 8″; Slate 0′ 2″; Coal 0′ 6″		1	4
11. Fire clay		1		
12. Limestone		1		
13. Fire clay, with limestone nodules in top		8		
14. Sandstone, shaly		7	52	
15. Concealed (shales)		15		
16. Blue shales		20		
17. Coal, Lower Kittanning	Coal 1′ 1″; Slate 0′ 1″; Coal 1′ 1″; Slate 0′ 1″; Coal 1′ 2″		3	6
18. Concealed to river level			20	
19. To base of Lower Coal Measures, about			80	
Total			298	6

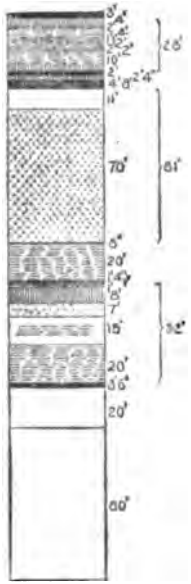

FIG. 65.—Section at Logansport, Pa.

Here we find a ferruginous limestone making its appearance under what the section shows to be the Middle Kittanning coal, and it is possible that this same bed may have occasionally been identified with the Johnstown Cement limestone in this portion of Pennsylvania, which would be erroneous, since that bed belongs under the little coal, No. 8 of the section, while the Johnstown Cement bed, as correlated by Messrs. Platt and others, comes just under the Upper Kittanning coal.

The section also exhibits the great variations that may take place in the thickness of the intervals between important coal beds, that between the two Freeports being here reduced to only 28 feet.

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Section at Freeport, Pennsylvania.—Freeport, on the Alleghany River, at the southern point of Armstrong County and 7 miles southwest of Logansport, is a classic locality for the upper portion of the Lower Coal Measures, and the following section (Fig. 66), taken there, is given for the purpose of illustrating the relations of the Upper and Lower Freeport coals at this typical locality:

Freeport, Pennsylvania.

[See map, G n.]

		Ft.	in.	Ft.	in.
1. Coal, Upper Freeport	Coal ..... 2′ 8″; Slate, gray ..... 0′ 1½″; Coal ..... 0′ 6½″; Slate, dark gray ..... 0′ 0½″; Coal, sulphurous ..... 0′ 5″			3	9½
2. Fire clay		1	6		
3. Limestone, Upper Freeport		3	6		
4. Sandy shales		20		66	
5. Coal, Middle Freeport		2			
6. Sandy shales and sandstone		39			
7. Coal, Lower Freeport	Cannel slate ... 5′ 0″; Slaty coal ..... 4′ 6″; Fire clay with limestone .... 2′ 6″; Slaty coal ..... 2′ 6″			14	
8. Fire clay and shales		2			
9. Sandstone, massive (Freeport sandstone)		45		64	
10. Coaly slate, Upper Kittanning (Freeport sandstone)		0–4			
11. Sandstone, gray, massive (Freeport sandstone)		15			
12. Coal, Middle Kittanning				1	6
13. Fire clay, with limestone nodules in upper half				6	
Total				155	3½

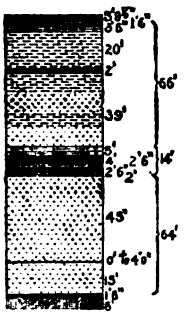

FIG. 66.—Section at Freeport, Pa.

This section shows that there is a third Freeport coal, coming nearly midway between the upper and lower ones, at this, their typical locality, a fact that has been frequently overlooked by geologists, and that has led to error in identifications. This Middle Freeport coal, as I have termed it, is not persistent; but the fact that there is such a bed in the series occasionally should lead to careful scrutiny of this portion of the column of rocks before positive identification of the Lower Freeport coal.

This latter bed, No. 7, also has elements of possible confusion in its structure here at its type locality, since, as may be seen from the section, it is a double bed, made so by 2½ feet of fire clay, in which a nodular limestone occurs. It is possible that these parting rocks may expand to several feet in some regions, and thus give two Lower Freeport coals, as indeed they are known to do.

I have included No. 11 as a part of the Freeport sandstone, since at one locality the coal bed No. 10 thins out entirely and lets Nos. 9 and 11 unite into one solid sandstone; but it is possible that No. 9 alone should be included under the name Freeport sandstone, as originally intended by Rogers.

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Section near mouth of Beaver River, Pennsylvania.—In the region about the mouth of the Beaver River, the Lower Coal Measures thicken up to a considerable extent, through the local expansion of some members, as shown by the following (Fig. 67) section of the structure there:

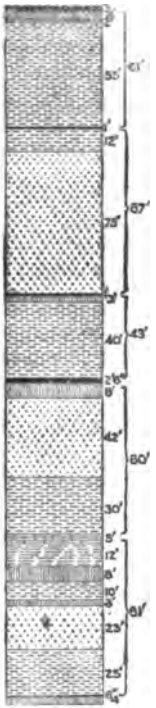

FIG. 67.—Section near mouth of Beaver River, Pa.

Near mouth of Beaver River, Beaver County, Pennsylvania.

[See map, G k.]

	Ft.	Ft.	in.
1. Coal, Upper Freeport		3	
2. Fire clay	4		
3. Limestone, Upper Freeport	2	61	
4. Shales, sandy	55		
5. Coal, Lower Freeport		1	
6. Shales, sandy	12		
7. Sandstone, massive, Freeport	75	87	
8. Coal, Middle Kittanning		1	
9. Fire clay	3		
10. Shales, sandy, dark	40	43	
11. Coal, Lower Kittanning		2	6
12. Fire clay	8		
13. Sandstone, flaggy and massive	42	80	
14. Shales, sandy	30		
15. Limestone, Ferriferous		5	
16. Black fossiliferous shales	12		
17. Fire clay	8		
18. Sandy shales	10		
19. Fire clay, non-plastic	3	81	
20. Sandstone, flaggy	23		
21. Shales, sandy	25		
22. Coal, Brookville		0	6
23. Fire clay		4	
24. Massive sandstone, No. XII.			
Total		369	

Section at Sewickley, Pennsylvania.—At Sewickley, Alleghany County, Pennsylvania, a test hole for coal was bored by Mr. Cochran Fleming, through whose courtesy the writer had the opportunity of measuring the carefully preserved cores from the diamond drill, which gave this structure (Fig. 68) for the rocks of the Lower Coal Measures there:

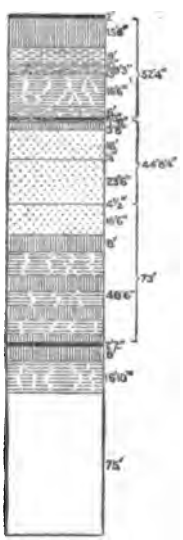

FIG. 68.—Section at Sewickley, Pa.

Sewickley, Alleghany County, Pennsylvania.

[See map, H l.]

	Ft.	in.	Ft.	in.
1. Coal, Upper Freeport			2	
2. Fire clay	15	6		
3. Shales, blue, sandy	9	0		
4. Sandstone	0	10		
5. Fire clay	3	3	52	4
6. Sandstone	1	3		
7. Shales	16	6		
8. Dark slate	6	0		
9. Coal, slaty, Lower Freeport			1	3
10. Fire clay, good	1	6		
11. Fire clay, sandy	3	8		
12. Gray, micaceous sandstone in thin layers Freeport { Sandstone 16′ 0″; Coal 0′ 0¼″; Sandstone 23′ 0″ }	39	6¼	44	8¼
13. Coal, Upper Kittanning			0	4½
14. Sandstone	16	6		
15. Fire clay (Middle Kittanning coal horizon)	8		73	
16. Shales, dark, interstratified with fire clay	48	6		
17. Coal, Lower Kittanning { Coal 1′ 4″; Slate 0′ 1″; Coal 0′ 9″ }			2	2
18. Fire clay, good			8	
19. Shales, blue			16	10
20. Interval to top of No. XII, estimated			75	
Total			275	8

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Section at Washington, Pennsylvania.—At Washington, Pennsylvania, the top of this series is 1,000 feet below the surface, and Prof. Linton, of Washington and Jefferson College, gives the following (Fig. 69) as the structure of its rocks according to the record of the Thayer oil well, the drillings from which he very carefully studied (Geological Survey of Pennsylvania, 1886, pp. 764, 765):

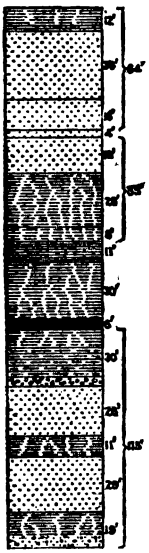

FIG 69.—Section under Washington, Pa.

Under Washington, Pennsylvania.

[See map, J k.]

		Ft.	Ft.
1.	Upper Freeport coal—absent		
2.	Dark shale with limestone at bottom, Upper Freeport	12	
3.	Sandstone, dark	36	64
4.	Sandstone, white	16	
5.	Sandstone, dark, with limestone		4
6.	Sandstone, hard	19	
7.	Shale, dark	28	55
8.	Shale, variegated with dark lime	8	
9.	Limestone, Johnstown Cement .. { dark .. 3′ / light . 8′ }		11
10.	Shale, dark, slaty		30
11.	Shale and coal, Middle Kittanning		6
12.	Shale, slate and shells	30	
13.	Sandstone, grayish	26	
14.	Shale, gray	11	115
15.	Sandstone, grayish, shaly	29	
16.	Shale and shells	19	
	Total		285

Here there is only one coal present in the series and it would appear to be the Middle Kittanning.

Section near Carpenter's Station, Westmoreland County, Pennsylvania.—Near the main line of the Pennsylvania Railroad, in the vicinity of Carpenter's Station, Westmoreland County, Pennsylvania, a well was drilled for gas by Mr. E. M. Hukill, who thus (Fig. 70) reports the structure of the Lower Coal Measures, as published in Geological Survey of Pennsylvania, 1886, p. 726:

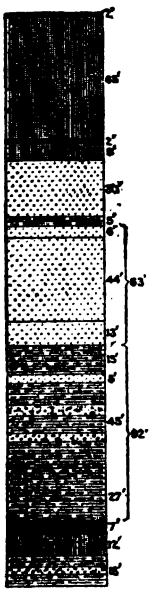

FIG. 70.—Section near Carpenter's Station, Pa.

Near Carpenter's Station, Westmoreland County, Pennsylvania.

[See map, I n.]

		Ft.	Ft.
1.	Coal, Upper Freeport		2
2.	Fire clay (shales)		65
3.	Coal, Lower Freeport		2
4.	Fire clay	9	
5.	Sandstone, gray	30	
6.	Slate	5	107
7.	Sandstone, Freeport ... { Sandstone, hard . 6′ / Sandstone, soft . 44′ / Sandstone, hard . 13′ }	63	
8.	Slate	15	
9.	Sandstone	5	92
10.	Slate and shells	45	
11.	Slate, black	27	
18.	Coal, Clarion or Lower Kittanning		7
19.	Fire clay		12
20.	Shale and shells		16
21.	Sandstone, top of XII.		
	Total		303

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Section under Murraysville, Pennsylvania.—At Murraysville, Westmoreland County, Pennsylvania, in the celebrated natural gas region, the top of the Lower Coal Measures lies 60 to 75 feet below the surface, and the structure of the series is thus given (Fig. 71) by Mr. Doubleday, from the records of a gas well on the Remaley farm, Geological Survey of Pennsylvania, 1886, p. 721:

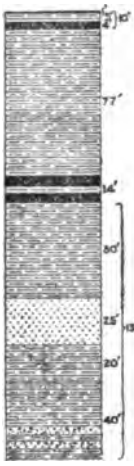

FIG. 71.—Section under Murraysville, Pa.

Under Murraysville, Westmoreland County, Pennsylvania.

[See map, I n.]

	Ft.	Ft.
1. Coal, Upper Freeport..... { Coal.....1′ Slate.....5′ Coal.....4′ }		10
2. Slate		77
3. Coal, slate in center		14
4. Slate	50	135
5. Sandstone	25	
6. Slate	20	
7. Slate and shells	40	
8. Massive sandstone, top of XII.		
Total		236

Section on Beaver Run, Westmoreland County, Pennsylvania.—About 9 miles northeast of Murraysville a well was drilled on Beaver Run, beginning only 4 feet below the level of the Upper Freeport coal. The record (Fig. 72) of this well, as given by Mr. J. A. Mehaffey, shows the following structure there (Pennsylvania Geological Survey, 1886, p. 728):

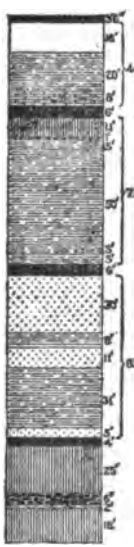

FIG. 72.—Section on Beaver Run, Pa.

Beaver Run, Westmoreland County, Pennsylvania.

[See map, H n.]

	Ft.	Ft. in.
1. Coal, Upper Freeport		3 6
2. Concealed	16	44
3. Black slate	20	
4. Limestone	8	
5. Coal, Lower Freeport		6
6. Fire clay	11	77
7. Shell, hard	1	
8. Shale, soft	5	
9. Slate, black	50	
10. Shale, soft	5	
11. Slate, black	5	
12. Coaly slate, Upper Kittanning		6
13. Sandstone	30	85
14. Slate, black	8	
15. Sandstone, gray	11	
16. Slate, black	31	
17. Sandstone	5	
18. Coal, Lower Kittanning		4
19. Fire clay		25
20. Iron ore		6
21. Shales, soft		2
22. Fire clay		18
23. Pebbly sandstone, top of XII.		
Total		276 6

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Section near Richmond, Pennsylvania.—In the northern portion of Indiana County, Pennsylvania, in the vicinity of Richmond village, the Lower Coal Measures exhibit the following structure (Fig. 73) according to Mr. Wm. G. Platt, H⁴, p. 266:

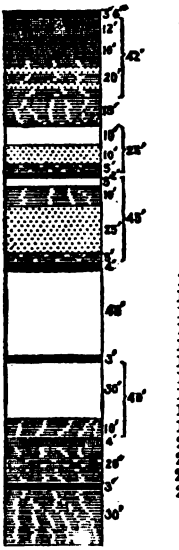

FIG. 73.—Section near Richmond, Pa.

Near Richmond, Indiana County, Pennsylvania.

	[See map, F p.]	Ft.	Ft.	in.
1.	Coal, Upper Freeport		3	6
2.	Clay	12		
3.	Limestone	10	42	
4.	Shales and thin sandstone	20		
5.	Coal, Lower Freeport ... { Coal... thin; Shales. 15'; Coal... thin }		15	
6.	Concealed	10		
7.	Sandstone	10	25	
8.	Clay slate	5		
9.	Coal, Upper Kittanning		2	
10.	Concealed	5		
11.	Shales	10		
12.	Sandstone	25	45	
13.	Slate and shales	5		
14.	Coal, Middle Kittanning		4	
15.	Interval		45	
16.	Coal, Lower Kittanning		3	
17.	Interval	30	40	
18.	Shales	10		
19.	Limestone, Ferriferous		4	
20.	Shales and slates		20	
21.	Coal, Clarion		3	
22.	Shales		30	
23.	Sandstone, massive, top of XII.			
	Total		281	6

Section near Lockport and Bolivar, Indiana County, Pennsylvania.—In the vicinity of Bolivar and Lockport just east of the Chestnut Ridge anticlinal, Mr. Wm. G. Platt finds the following succession (Fig. 74) for these measures as given in H⁴, p. 65:

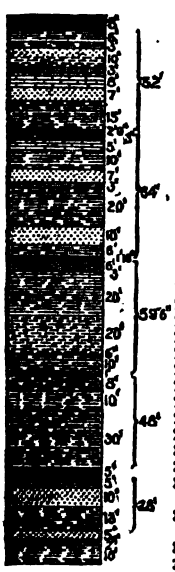

FIG. 74.—Section near Lockport and Bolivar, Pa.

Near Lockport and Bolivar, Indiana County, Pennsylvania.

	[See map, I p.]		Ft.	in.
1.	Coal, Upper Freeport		8	
2.	Clay shales	6		
3.	Shales, with ore masses	3		
4.	Sandstone and sandy shales	10		
5.	Fire clay, good	3	52	
6.	Limestone, impure, Upper Freeport	8		
7.	Thin bedded sandstone	7		
8.	Clay slates and shales	15		
9.	Coal, Lower Freeport		2	9
10.	Clay, impure	3		
11.	Limestone, Lower Freeport	5		
12.	Clay shales	10		
13.	Sandstone	7		
14.	Sandy fire clay	3	64	
15.	Slates and shales	20		
16.	Sandstone	10		
17.	Grayish slates	6		
18.	Coal, Upper Kittanning		1	10
19.	Fire clay, impure	6		
20.	Limestone, Johnstown cement	3		
21.	Dark slates and shales	20		
22.	Sandy shales with ore nodules	20	59	6
23.	Carbonate iron ore band	0 6		
24.	Black slates	10		
25.	Coal, Middle Kittanning		1	
26.	Slates	8		
27.	Shales	10	48	
28.	Black slate and shale	30		
29.	Coal, Lower Kittanning		5	
30.	Clay	5		
31.	Sandstone	10	28	
32.	Shales and clay slates	13		
33.	Clarion coal ... { Coal ..... thin; Sandstone.. 5'; Coal..... 1' }		6	
34.	Fire clay		2	
35.	Shales		10	
36.	Sandstone, heavy, compact.			
	Total		281	

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Section near Laughlinstown, Pennsylvania.—In the vicinity of Laughlinstown, Westmoreland County, and 10 miles south from Bolivar, Dr. Jno. J. Stevenson (KKK, p. 135) reports the Lower Coal Measures with the following structure (Fig. 75):

Laurel Run, Ligonier Township, Westmoreland County, Pennsylvania.

[See map, J p.]		Ft.	in.	Ft.	in.
1. Coal, Upper Freeport				4	
2. Clay		6			
3. Fire clay, non-plastic		2			
4. Sandstone		1			
5. Concealed		11		62	
6. Sandstone		1			
7. Concealed		29			
8. Shale		12			
9. Coal, Lower Freeport				0	6
10. Shales		10		18	
11. Concealed		8			
12. Coal, Upper Kittanning	Coal 1′ 6″; Shaly sandstone 5′ 0″; Coal 0′ 1″			6	7
13. Shale		1			
14. Limestone, Johnstown Cement	Limestone 1′ 6″; Shale 1′ 0″; Limestone 9′ 0″	11	6	42	6
15. Shale		30			
16. Coal, Middle Kittanning				3	6
17. Concealed		25			
18. Sandstone		25		51	6
19. Shale		1	6		
20. Coal, Lower Kittanning	Coal 1′ 10″; Clay 0′ 2″; Coal 1′ 0″; Coal, slaty 0′ 6″; Carbonaceous shale 1′ 8″			5	2
21. Clay				5	
22. Massive sandstone, coarse				35	
23. Shale				20	
24. Iron ore					
25. Shale				15	
26. Coal, Clarion				2	
27. Shale				25	
28. Top of No. XII.					
Total				295	9

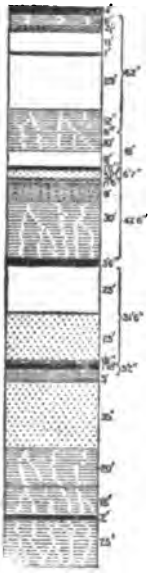

FIG. 75.—Section on Laurel Run, Pa.

Section on Cucumber Run, Stewart Township, Fayette County, Pennsylvania.—In this same basin (Ligonier) and on southwestward near the Youghiogheny River, in Fayette County, the Lower Coal Measures exhibit the following structure (Fig. 76) on Cucumber Run, as reported by Stevenson (KKK, p. 89):

Cucumber Run, Stewart Township, Fayette County, Pennsylvania.

[See map, K n.]		Ft.	Ft.	in.
1. Coal, Upper Freeport			3	
2. Clay		3		
3. Limestone, Freeport		5	44	
4. Fire clay, Bolivar, and shale		16		
5. Shale, sandy		20		
6. Coal, Lower Freeport (?)			0	8
7. Shale, sandy			30	
8. Coal, Upper Kittanning (?)	Coal 2′ 3″; Clay 0′ 4″; Coal 3′ 4″		5	11
9. Clay		3		
10. Sandstone, Freeport (?)		40	83	
11. Concealed (mostly sandstone)		40		
12. Coal, Middle Kittanning			blossom	
13. Sandstone		10	35	
14. Concealed		25		
15. Coal, Lower Kittanning			blossom	
16. Concealed			60	
17. Coal, Clarion or Brookville			2	3
18. Shale and clay			10	
19. Sandstone, massive, top of XII.				
Total			273	10

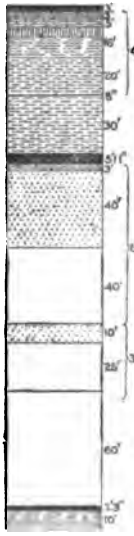

FIG. 76.—Section on Cucumber Run, Fayette County, Pa.

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Section at Newburg, West Virginia.—Newburg, on the Baltimore and Ohio Railroad, in Preston County, West Virginia, is situated at the center of the same coal basin as Bolivar, Ligonier, etc., and there a deep shaft reveals the following structure (Fig. 77) for the Lower Coal Measures:

Shaft at Newburg, Preston County, West Virginia.

[See map, O m.]

		Ft. in.	Ft. in.
1. Coal, Upper Freeport	Coal ..... 3′; Coal and slate .. 2′ 4″		5 4
2. Shales		8	
3. Sandstone		18	
4. Limestone, Upper Freeport		8	
5. Shales		6	45
6. Iron ore		1	
7. Shales		4	
8. Fire clay (horizon of Lower Freeport coal)			2
9. Shales, gray		14	
10. Shale, dark		11	
11. Shale, gray		9	108
12. Sandstone, Freeport		74	
13. Coal, Upper and Middle Kittanning	Coal ..... 1′ 0″; Slate ..... 0′ 3″; Coal, slaty . 2′ 0″; Fire clay .. 2′ 0″; Coal, good . 2′ 0″		7 3
14. Fire clay and shales with iron ore nodules			15
15. Coal, Lower Kittanning	Coal .....0′ 10″; Shale, gray.....0′ 10″; Coal .....0′ 6″; Coal, bony .....0′ 3″; Coal, main bench .4′ 6″; Black slate .....0′ 6″; Coal .....2′ 0″		9 5
16. Sandstone and shale			38
17. Pebbly sandstone, top of XII.			
Total			230

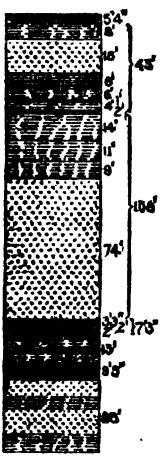

FIG. 77.—Section at Newburg, W. Va.

Here the Upper Freeport coal lies 150 feet below drainage and 700 feet below the tops of the immediate hills.

No. 13 appears to represent both the Upper and Middle Kittanning coal beds, which are brought practically together, and also very close to the Lower Kittanning bed by the thinning away of intervening rocks.

The interval under the Lower Kittanning bed here is revealed by a diamond drill hole which was put down 150 feet below the latter stratum.

The Lower Freeport coal is not present, but its horizon is clearly indicated by the bed of fire clay, No. 8, at 45 feet under the Upper Freeport coal.

The Freeport sandstone, No. 12, has a large development, and where it comes to the surface, 4 miles above Newburg, is nearly 100 feet thick.

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Section at Johnstown, Pennsylvania.—Johnstown, Pennsylvania, lies just east of the Laurel Hill anticline, and the Lower Coal Measures have there been splendidly exposed through the mining operations of the Cambria Iron Company. The following section (Fig. 78) of the rocks in that region is given by the chief engineer of the Cambria Company, Mr. John Fulton (H^3, pp. 308, 309):

Vicinity of Johnstown, Cambria County, Pennsylvania.

[See map, I q.]

	Ft.	in.	Ft.	in.
1. Coal, Upper Freeport			3	0
2. Fire clay	1			
3. Shales	5			
4. Sandstone	10			
5. Shales	5			
6. Kidney ore	0	10	54	10
7. Shales	15			
8. Sandstone	15			
9. Shales	3			
10. Coal, Lower Freeport			2	6
11. Shale	0	6		
12. Limestone, Lower Freeport	3			
13. Iron-stained shales	17		45	6
14. Sandstone, gray, micaceous	21			
15. Slates	4			
16. Coal, Upper Kittanning			3	6
17. Fire clay	0	9		
18. Limestone, Johnstown Cement	5			
19. Fire clay, impure	7		39	9
20. Slates, with iron ore	8			
21. Slate	8			
22. Black slates, with iron ore	11			
23. Coal, Middle Kittanning { Coal 0′ 3″; Slate 1′ 0″; Coal 0′ 3″ }			1	6
24. Thin black slates	13			
25. Coal	0	9		
26. Fire clay	4			
27. Sandstone, gray	13		40	9
28. Sandstone, wavy, gray	4			
29. Iron-stained slates	6			
30. Coal, Lower Kittanning			3	6
31. Fire clay	3			
32. Gray slates and shales	21			
33. Massive black shales	15			
34. Gray sandstone	5			
35. Massive black slate	5		60	0
36. Coal, thin				
37. Black slates	1			
38. Gray sandstone	4			
39. Thin gray slates	6			
40. Coal, Clarion { Coal 4′ 0″; Slate 0′ 6″; Coal 1′ 10″ }			6	10
41. Fire clay			3	0
42. Gray slates			28	0
43. White massive sandstone, top of XII.				
Total			292	8

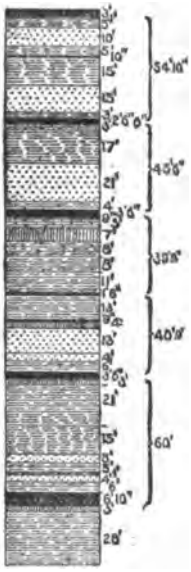

FIG. 78.—Section near Johnstown, Pa.

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Section at Conemaugh, near Johnstown, Pennsylvania.—The writer compiled a section of the Lower Coal Measures at Conemaugh and elsewhere in the vicinity of Johnstown, which differs only in minor details from that of Mr. Fulton. It reads as follows (Fig. 79):

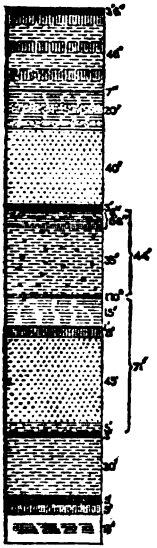

FIG. 79.—Section at Conemaugh, Pa.

Near Johnstown, Pennsylvania.

[See map, I q.]	Ft.	in.	Ft.	in.
1. Coal, Upper Freeport			3	6
2. Fire clay and sandy shales			40	
3. Coal, Lower Freeport			0	7
4. Shales and sandy beds			20	
5. Sandstone, massive			40	
6. Coal, Upper Kittanning			3	
7. Shale	0	6		
8. Limestone, Johnstown Cement { Limestone 2′ 6″; Shale and iron ore 1′ 6″; Limestone 4′ 6″ }	8	6	44	0
9. Dark sandy shales with iron ore	35			
10. Coal, Middle Kittanning { Coal and slate 0′ 6″; Slate 0′ 6″; Slaty coal 0′ 10″ }			1	10
11. Shales, drab	15			
12. Coal	1			
13. Impure fire clay	5		71	
14. Sandstone, gray micaceous	45			
15. Sandy shales	5			
16. Coal, Lower Kittanning			3	
17. Shales, sandy			30	
18. Coal, Clarion			5	
19. Fire clay			5	
20. Concealed and shales			15	
21. Top of XII.				
Total			281	11

Section in Jackson Township, Cambria County, Pennsylvania.—In Jackson Township, Cambria County, 8 miles northeast of Johnstown, a well was once drilled for oil, and I obtained from the contractor the following record (Fig. 80) of the strata representing the Lower Coal Measures. It is chiefly important as giving the total thickness of the series in a vertical measurement:

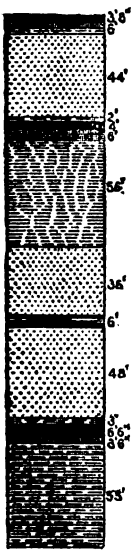

FIG. 80.—Section in Jackson Township, Cambria County, Pa.

Jackson Township, Cambria County, Pennsylvania.

[See map, I q.]

	Ft.	in.
1. Coal, Upper Freeport	3	8
2. Fire clay and slate	6	
3. Sandstone, gray	44	
4. Slate, drab	2	
5. Coal, Lower Freeport	4	
6. Fire clay and limestone	6	
7. "Soapstone" (shale)	56	
8. Sandstone, gray	36	
9. Coal and slate, Lower Kittanning	6	
10. Sandstone, gray	48	
11. Shale	3	
12. Coal, Clarion	6	6
13. Fire clay	3	6
14. Slate, gray	55	
15. Hard sandstone, top of XII.		
Total	279	8

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Section on Ben's Creek, Cambria County, Pennsylvania.—Near the eastern border of Cambria County, along the waters of Ben's Creek, in Washington Township, the following section (Fig. 81) is reported by Mr. Franklin Platt (H^3, p. 48):

Ben's Creek, Cambria County, Pennsylvania.

[See map, I q.]

	Ft.	in.	Ft.	in.
1. Coal, Upper Freeport			4	4
2. Fire clay	6			
3. Black slates and shales	15			
4. Limestone, Upper Freeport	7		55	
5. Interval	15			
6. Sandstone	12			
7. Coal, Lower Freeport { Coal 0′ 2″; Sandstone 2′ 0″; Fire clay and shale 6′ 0″; Coal 2′ 0″ }			10	2
8. Fire clay	2			
9. Limestone, Lower Freeport	2	6		
10. Shales, iron-bearing	15			
11. Coal, smut	0	2		
12. Fire clay, shales, with ore balls	5		38	11
13. Coal, smut	0	3		
14. Fire clay	1			
15. Slates and shales	6			
16. Black slates	7			
17. Coal, Upper Kittanning			2	6
18. Fire clay	1	9		
19. Drab shales	25			
20. Sandstone, fine grained	30		56	9
21. Black slate	0	3		
22. Coal, slaty, Middle Kittanning			2	
23. Fire clay				
24. Sandstone	5			
25. Fire clay, shale	10		29	
26. Black slate	5			
27. Coal, Lower Kittanning			3	
28. Sandstone and shale			18	
29. Coal, Clarion			5	
30. Fire clay	5			
31. Sandstone	0	10		
32. Dove-colored shale, with ore	10		29	10
33. Sandstone	3			
34. Fire clay, shale	2			
35. Coal, Brookville			1	8
36. Fire clay				
37. Concealed			25	
38. Top of XII.				
Total			263	2

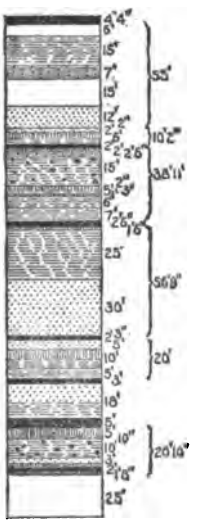

FIG. 81.—Section on Ben's Creek, Cambria County, Pa.

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Section near Stoyestown, Pennsylvania.—In the vicinity of Stoyestown, on Stony Creek, Somerset County, Pennsylvania, near the center of the basin between the Viaduct and Negro Mountain anticlines, the series exhibits the following structure (Fig. 82) according to Mr. Franklin Platt (H^3, p. 129):

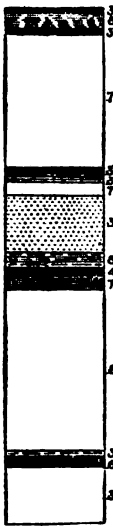

FIG. 82.—Section near Stoyestown, Pa.

Stoyestown, Somerset County, Pennsylvania.

[See map, J q.]

		Ft.	in.	Ft.	in.
1. Coal, Upper Freeport	Coal 3′, Shale 8′, Coal 3′			14	
2. Interval				70	
3. Black slates				1	
4. Coal, Lower Freeport		3			
5. Fire clay		2			
6. Limestone, Lower Freeport		3		53	
7. Interval		7			
8. Sandstone, massive		30			
9. Black slates		8			
10. Coal, Upper Kittanning				4	
11. Black slate		0	6		
12. Limestone, Johnstown Cement		7			
13. Fire clay		1		95	6
14. Interval		85			
15. Black slates		3			
16. Coal, Clarion				6	
17. Interval, concealed				30	
18. Top of No. XII.					
Total				272	6

Section at Pinkerton Point, Pennsylvania.—On the Castleman River at Pinkerton Point, in the southern portion of Somerset County, a very complete section of the Lower Coal Measures was obtained by Mr. Franklin Platt along the Baltimore and Ohio Railroad, near Shoo Fly Tunnel, and is reported as follows (Fig. 83) (H^3, pp. 202, 203):

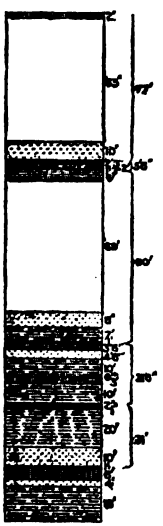

FIG. 83.—Section at Pinkerton Point, Somerset County, Pa.

Pinkerton Point, Somerset County, Pennsylvania.

[See map, L o.]

		Ft.	in.	Ft.	in.
1. Upper Freeport Coal (absent)					
2. Limestone, ferruginous, Upper Freeport		2			
3. Interval		65		77	
4. Sandstone		10			
5. Coal, Upper Kittanning	Coal 2′ 3″, Shale and fire clay 2′ 0″, Coal 1′ 3″			5	6
6. Limestone, Johnstown Cement		6			
7. Interval		69		90	
8. Sandstone		8			
9. Black slate		7			
10. Coal, Middle Kittanning				1	
11. Fire clay, with ore		3	6		
12. Sandstone		4	6		
13. Black slates		10		31	6
14. Coal		0	6		
15. Fire clay with iron-ore balls		3			
16. Slate and clay		10			
17. Coal, Lower Kittanning				2	
18. Fire clay		1			
19. Shales, with ore balls		20		31	
20. Sandstone, brownish		10			
21. Coal, Clarion				1	
22. Fire clay				6	
23. Sandstone				4	
24. Slates, dark colored				18	
25. Massive sandstone, top of No. XII.					
Total				267	

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Section near Cresson, Pennsylvania.—An oil boring near Cresson, on the summit of the Alleghany Mountains, gives the following measurements (Fig. 84) for the Lower Coal Measures (H^2 page 30):

FIG. 84.—Section near Cresson, Pa.

Boring at Cresson, Cambria County, Pennsylvania.

[See map, H r.]

	Ft.	in.
1. Coal, Upper Freeport	5	
2. Limestone, Upper Freeport	2	
3. Mixed drilling	39	
4. Coal, Lower Freeport	4	
5. Shelly "soapstone" (sandstones and shales)	115	
6. Cannel coal	0	10
7. Slate	35	
8. Coal, mixed with sandstone	49	
9. Hard sandstone (No. XII).		
Total	249	10

Section at Bennington, Pennsylvania.—Just over the crest of the Alleghany Mountains, at Bennington, Blair County, the following section (Fig. 85) of this series has been carefully worked out by Mr. John Fulton and Franklin Platt (H^2, pp. 3, 4):

Bennington, Blair County, Pennsylvania.

[See map, H r.]

	Ft.	in.	Ft.	in.
1. Coal, Upper Freeport			5	6
2. Fire clay, impure	2			
3. Sandstones and black slates	20			
4. Limestone, Upper Freeport	3		65	
5. Ferruginous slates and shales	20			
6. Sandstones and sandy shales	20			
7. Coal			3	
8. Fire clay	1			
9. Sandstone, drab	21		42	
10. Black slates	20			
11. Coal, Upper Kittanning			2	10
12. Drab slates, with iron balls	11			
13. Sandstone	0	7		
14. Blue slates	13		53	1
15. Sandstone, massive	15			
16. Slates	12	6		
17. Coal, Middle Kittanning { Coal 0′ 6″; Slate 0′ 6″; Coal 1′ 5″ }			2	8
18. Fire clay, impure	6			
19. Sandstone	12			
20. Slate	1	3	35	5
21. Coal	0	4		
22. Sandstone	7			
23. Black slates	8	10		
24. Coal, Lower Kittanning			3	6
25. Fire clay, good	8			
26. Shales	29		34	
27. Black slates	2			
28. Coal, Clarion			1	8
29. Slates	23		27	
30. Gray sandstone	4			
31. Coal, Brookville			4	
32. Fire clay			5	
33. Sandstone, massive, No. XII.				
Total			283	8

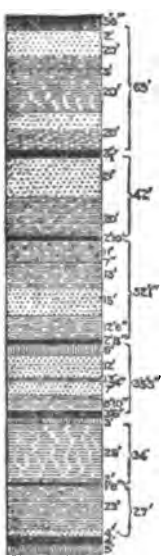

FIG. 85.—Section at Bennington, Pa.

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Section at Clearfield, Pennsylvania.—At the town of Clearfield, Clearfield County, Pennsylvania, the following section (Fig. 86) was made by the writer:

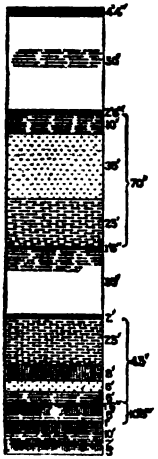

FIG. 86.—Section at Clearfield, Pa.

Clearfield, Pennsylvania.

[See map, E s.]		Ft.	Ft.	in.
1. Coal, Upper Freeport	Coal, bony. 1′ 3″; Coal, good. 1′ 6″; Slate ..... 0′ 1″; Coal ..... 1′ 6″		4	4
2. Concealed, and shales			50	
3. Coal, Lower Freeport			2	6
4. Shales		10		
5. Sandstone, massive, gray, Freeport		35	70	
6. Shales, sandy		25		
7. Coal, Middle Kittanning			1	6
8. Shales, and concealed			35	
9. Coal, Lower Kittanning			2	
10. Sandy shales		25		
11. Fire clay		8	45	
12. Sandstone, flaggy		6		
13. Shales, dark		6		
14. Coal, Clarion	Coal, slaty ..... 1′ 6″; Fire clay and shales. 8′ 0″; Coal, good ..... 1′ 0″		10	6
15. Fire clay and shales			10	
16. Coal, Brookville	Coal, slaty. 0′ 4″; Shale ..... 0′ 12″; Coal ..... 0′ 8″		2	
17. Fire clay and concealed			5	
18. Hard massive sandstone, top of No. XII, in bed of Susquehanna River.				
Total			237	10

Section near Morrisdale, Pennsylvania.—Near Morrisdale, Clearfield County, the following section (Fig. 87) is reported by Mr. H. Martyn Chance (H^7, p. 61):

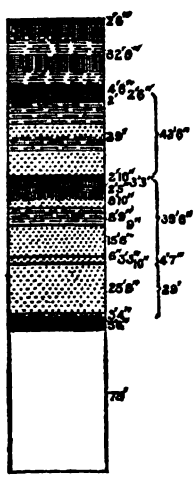

FIG. 87.—Section near Morrisdale, Pa.

Near Morrisdale, Clearfield County, Pennsylvania.

[See map, F t.]		Ft.	in.	Ft.	in.
1. Coal, Upper Freeport				2	6
2. Fire clay and shales				32	6
3. Coal, Lower Freeport				4	6
4. Fire clay		2	6		
5. Limestone, Lower Freeport		2		43	6
6. Slate and sandstone		39			
7. Coal, Upper Kittanning				2	10
8. Fire clay		3	3		
9. Limestone, Johnstown Cement		2	5		
10. Fire clay and sandstone with iron ore		8	10	39	6
11. Black slate		8	9		
12. Coal		0	9		
13. Sandstone		15	6		
14. Coal, Middle Kittanning	Coal ..... 0′ 6″; Sandstone. 3′ 3″; Coal ..... 0′ 10″			4	7
15. Sandstone		25	8	29	
16. Slate		3	4		
17. Coal, Lower Kittanning				5	6
18. Interval to top of No. XII, estimated, about				75	
Total				239	5

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Section at Sterling Mines, near Houtzdale, Pennsylvania.—At the Sterling mines of R. H. Powell's Sons & Co., Clearfield County, a diamond-drill boring was sunk through the Lower Coal Measures, beginning 10 feet below the level of the main coal mined in that region. I copied the record of this bore hole from the office of the company, and it, combined with the surface exposures, gives the following succession (Fig. 88):

Boring at Sterling Mines, near Houtzdale, Clearfield County, Pennsylvania.

[See map, G 8.]

			Ft.	Ft.	in.
1. Coal, Upper Freeport	Bone coal	0′ 10″		5	4
	Coal, sometimes a thin slate in center	4′ 6″			
2. Concealed			10	42	
3. Surface material in drill hole			16		
4. Dark slate			16		
5. Coal, Lower Freeport	Black shale and coal	1′ 6″		13	
	Shale, sandstone, and slate	8′ 6″			
	Soft shale	1′ 0″			
	Sandstone	1′ 0″			
	Coal	1′ 0″			
6. Sandy shale			5	50	
7. Hard sandstone, Freeport			31		
8. Dark slate			14		
9. Coal, Upper Kittanning				3	
10. Fire clay			2	33	
11. Dark slate			31		
12. Coal, Middle Kittanning				1	
13. Slate			3	19	
14. Sandy shale			9		
15. Slate			7		
16. Coal, Lower Kittanning				4	
17. Fire clay			1	63	
18. Slate			9		
19. Sandstone, close, hard			32		
20. Shales			21		
21. Coal, Clarion				3	6
22. Hard slate				4	6
Total				241	4

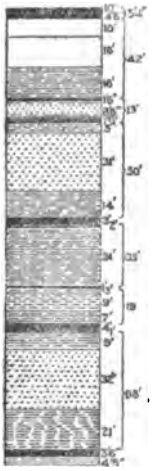

FIG. 88.—Section at Sterling Mines, near Houtzdale, Pa.

The coal at the top of this last section has been identified as the Lower Freeport bed, throughout the Clearfield region, by Messrs. Platt, Chance, and other Pennsylvania geologists; but it seems to me that this section, taken in connection with the one at Clearfield (Fig. 86), tends to prove that the coal in question is the Upper Freeport. This interpretation is further confirmed by the presence of the Lower Mahoning sandstone on above No. 1, and a thin coal, the Mahoning bed, at 60 to 80 feet above the latter, while crowning the hills is the Upper Mahoning sandstone, whose top is 100 feet above No. 1. Then, too, the structure of the coal itself is the same as the Upper Freeport, a few miles distant, where it is mined along the Pennsylvania Railroad, in the edge of Blair County.

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Section at Shoup's Run, Broad Top Basin, Huntingdon County, Pennsylvania.—In the Broad Top coal basin, Shoup's Run, Huntingdon County, Pennsylvania, the Lower Coal Measures exhibit the following structure (Fig. 89), as given by the writer in T³, Geological Survey of Pennsylvania, page 46:

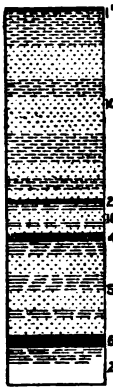

FIG. 89.—Section at Shoup's Run, Broad Top Basin, Huntingdon County, Pa.

Shoup's Run, Broad Top Basin, Huntingdon County, Pennsylvania.

[See map, J t.]

	Ft.
1. Coal, Upper Freeport	1
2. Sandy shales and sandstone	100
3. Coal, Upper Kittanning	2
4. Shales and sandstone	16
5. Coal, Middle Kittanning	4
6. Shales and shaly sandstone	50
7. Coal, Lower Kittanning	6
8. Shales and concealed	20
9. Massive conglomerate.	
Total	199

Section in East Broad Top Basin, Huntingdon County, Pennsylvania.—In the East Broad Top region of Huntingdon County the structure is thus (Fig. 90) given by Mr. H. N. Sims (T³, p. 68):

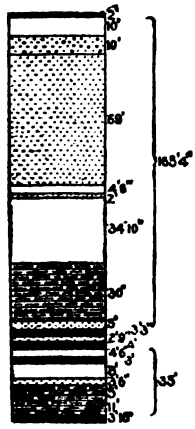

FIG. 90.—Section in East Broad Top Basin, Huntingdon County, Pa.

East Broad Top Basin, Huntingdon County, Pennsylvania.

[See map, J t.]

	Ft.	in.	Ft.	in.
1. Coal and slate, Upper Freeport			2	
2. Concealed	10			
3. Conglomerate, small pebbles	10			
4. Massive, light gray, pebbly sandstone, slightly argillaceous at top	69			
5. Concealed	4	6	165	4
6. Sandstone, micaceous	2			
7. Concealed to top of shaft	34	10		
8. Dark gray slate with iron ore balls	30			
9. Sandstone, micaceous, dark gray	5			
10. Coal, Upper Kittanning { Coal 2' 7", Black slate 0' 5", Coal 0' 3" }			3	3
11. Sandstone, slaty			2	9
12. Coal, Middle Kittanning			4	
13. Concealed	4	6		
14. Blue clay shales	3			
15. Concealed	8			
16. Yellow shaly sandstone	3	6	35	
17. Dark gray sandy slate	5			
18. Black slate, sandy	11			
19. Coal, Lower Kittanning { Coal, top bench 1' 6", Hard slate, parting 0' 4", Coal, bottom bench 2' 0" }			3	10
Total			216	2

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Section in Broad Top Basin, Bedford County, Pennsylvania.—In the Broad Top Basin of Bedford County, Pennsylvania, the structure is thus (Fig. 91) given by Stevenson (T^3, pp. 59 and 60):

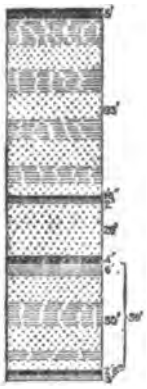

FIG. 91.—Section in Broad Top Basin, Pa.

Broad Top Basin, Bedford County, Pennsylvania.

[See map, J t.]

		Ft.	Ft.	in.
1.	Coal, Upper Freeport		5	
2.	Shales and sandstones		93	
3.	Coal, Upper Kittanning		1	6
4.	Clay		2	
5.	Sandstone		28	
6.	Coal, Middle Kittanning		4	
7.	Clay	6	56	
8.	Sandstone and shale	50		
9.	Coal, Lower Kittanning		2	6
10.	Clay		3	
11.	No. XII, conglomerate.			
	Total		195	

Section at Piedmont, West Virginia.—In the vicinity of Westernport, Maryland, where the North Potomac cuts across the Cumberland or George's Creek coal basin, the Lower Coal Measures exhibit the following succession (Fig. 92):

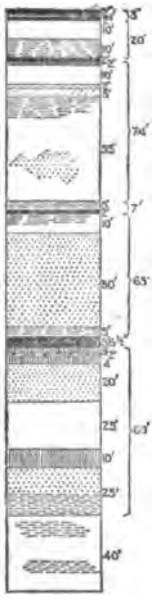

FIG. 92.—Section at Piedmont, W. Va.

Piedmont, Mineral County, West Virginia.

[See map, N p.]

		Ft.	Ft.	in.
1.	Coal, Upper Freeport: Coal 2′; Shale and bone 1′; Coal 2′		5	
2.	Concealed	10	20	
3.	Shale, bluish	10		
4.	Coal, Lower Freeport		2	
5.	Fire clay	2	74	
6.	Concealed	10		
7.	Sandstone, hard	2		
8.	Sandstone, shaly	5		
9.	Shales, sandstone, and concealed	55		
10.	Coal, Upper Kittanning: Bituminous slate 5′; Coal 2′		7	
11.	Dark shales, and concealed	10	65	
12.	Massive sandstone, gray	50		
13.	Shales, drab	5		
14.	Coal, Lower Kittanning: Coal, slaty 1′ 0″; Coal, bony 0′ 8″; Coal, good 1′ 4″; Slate, hard 0′ ½″; Coal, good 2′ 6″		5	6½
15.	Fire clay, sandy	3	89	
16.	Shales, with nodular iron ore	2		
17.	Fire clay, impure	4		
18.	Flaggy sandstone	20		
19.	Concealed	25		
20.	Fire clay, sandy	10		
21.	Flaggy sandstone and sandy shales	25		
22.	Concealed, and sandy shales		40	
23.	Top of No. XII.			
	Total		307	6½

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Section near Maple Swamp water tank, West Virginia Central Railroad, Mineral County, West Virginia.—Near Maple Swamp water tank, on the West Virginia Central Railroad, Mineral County, West Virginia, these beds exhibit the following structure (Fig. 93):

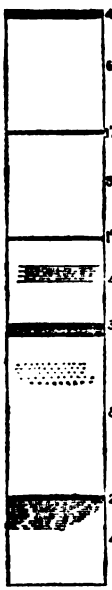

FIG. 93.—On North Potomac at Maple Swamp Water Tank, West Virginia Central Railroad.

On North Potomac at Maple Swamp water tank, West Virginia Central Railroad.

[See map, N p.]

		Ft.	in.
1. Coal, Upper Freeport	Coal 0′ 5″; Bone and slate 1′ 4″; Coal 2′ 6″	4	3
2. Concealed		60	
3. Coal, Lower Freeport		1	2
4. Concealed		55	
5. Coal, Upper Kittanning		1	
6. Concealed, and slate		45	
7. Coal, Lower Kittanning	Coal 3′ 0″; Slate 2′ 0″; Coal 1′ 5″	6	5
8. Concealed, and sandstone		85	
9. Coal, Clarion		2	6
10. Shales, and concealed		45	
11. Massive sandstone, top of No. XII.			
Total		305	4

Section near Thomas, West Virginia.—At the head of the North Potomac and on the Cheat River side of the great Alleghany watershed, we get a fine exposure of the Lower Coal Measures in the vicinity of Thomas, Tucker County, West Virginia. The exposures have been made by the mining and grading operations of the West Virginia Central Railroad, and there the section reads as follows (Fig. 94):

FIG. 94.—Near Thomas, Tucker County, W. Va.

Near Thomas, Tucker County, West Virginia.

[See map, O o.]

		Ft.	Ft.	in.
1. Coal, Upper Freeport	Coal 3′; Bone and bony coal 2′; Coal 3′		8	
2. Sandy shales, weathering reddish			40	
3. Coal, Lower Freeport	Coal 2″; Shale 4″; Coal 12″		1	6
4. Concealed		10	70	
5. Massive pebbly sandstone, Freeport		60		
6. Coal, streak, Upper Kittanning				
7. Fire clay and shales			35	
8. Coal, Middle and Lower Kittanning	Coal, good 1′ 5″; Slate 0′ 4″; Coal, good 1′ 0″; Slate 0′ 3″; Coal, good 3′ 6″; Shale, gray 1′ 6″; Coal, slaty 3′ 0″		11	
9. Concealed		5	65	
10. Massive sandstone		20		
11. Shales		2		
12. Iron ore, buhrstone		1		
13. Limestone, ferriferous		2		
14. Shales and sandstone		35		
15. Coal, Clarion			3	
16. Shales			40	
17. Sandstone, top of No. XII.				
Total			273	6

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Section near Moatsville, Barbour County, West Virginia.—Near Moatsville, Barbour County, West Virginia, on the Tygart's Valley River, the following section of the Lower Coal Measures is exposed (Fig. 95):

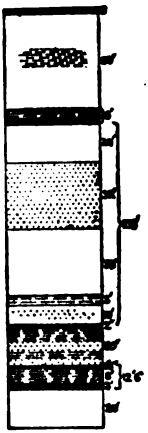

FIG. 95.—Section near Moatsville, W. Va.

Near Moatsville, Barbour County, West Virginia.

[See map, O m.]		Ft.	Ft.	in.
1. Coal, Upper Freeport			3	
2. Concealed, and sandy shales			50	
3. Coal, Lower Freeport	Slaty coal and slate 0′ 6″; Shale and fire clay 4′ 0″; Coal 2′ 0″; Dark bony clay 0′ 3″; Coal 1′ 3″		8	
4. Concealed		20		
5. Sandstone, massive, gray		35		
6. Concealed		35	105	
7. Dark blue shale		5		
8. Flaggy sandstone and concealed		10		
9. Limestone, gray, Campbell's Creek			2	
10. Shales, and massive sandstone			20	
11. Coal, Lower Kittanning	Coal 1′ 6″; Shales 8′ 0″; Coal 3′ 0″		12	6
12. Concealed			20	
13. White pebbly sandstone, top of No. XII.				
Total			220	6

Section near Valley Falls, West Virginia.—In the vicinity of Valley Falls, Taylor County, West Virginia, where the Chestnut Ridge anticline brings the series above water level, the following succession is visible (Fig. 96):

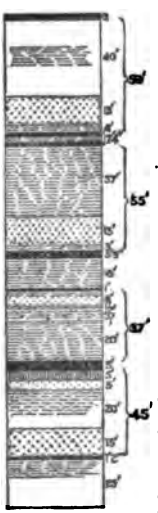

FIG. 96.—Section near Valley Falls, W. Va.

Valley Falls, Taylor County, West Virg nia.

[See map, N 1.]		Ft.	Ft.	in.
1. Coal, Upper Freeport			3	
2. Concealed and shales		40		
3. Sandstone		15	59	
4. Blue shales		4		
5. Coal, Lower Freeport	Coal 0′ 3″; Slate, gray 0′ 6″; Coal 1′ 3″; Shale 2′ 11″; Coal, bony cannel 0′ 6″; Shale, gray 0′ 8″; Coal 1′ 3″		7	4
6. Dark shales		37		
7. Sandstone, Freeport		15	55	
8. Shales, blue		3		
9. Coal, Upper Kittanning	Coal 3′ 1″; Shale, gray 0′ 1″; Coal, bony 0′ 7″		3	9
10. Shales, dark grayish			16	
11. Coal, Middle Kittanning			1	
12. Shales and flaggy sandstone		8		
13. Limestone, siliceous		1		
14. Sandstone, flaggy		3		
15. Shales, containing iron ore nodules		5	37	
16. Limestone, dark blue, Campbell's Creek		1		
17. Shales		20		
18. Coal, Lower Kittanning			5	
19. Fire clay		5		
20. Sandstone, flaggy		5		
21. Sandy shales, and concealed		20	45	
22. Sandstone, hard, micaceous		15		
23. Coal, Clarion	Coal 0′ 2″; Shale 0′ 10″; Coal 0′ 2″		1	2
24. Shales, and concealed			25	
25. Sandstone, massive, top of No. XII.				
Total			258	3

In this last section, and also in the preceding one (Fig. 95), a bed of impure, siliceous limestone occurs in the shale interval above the Lower

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Kittanning coal. It occupies the same geological horizon as the thin, siliceous limestone above the Campbell's Creek (Lower Kittanning) coal on the Big Kanawha River, and hence I have identified it with that stratum.

Section near Nuzum's Mill, Marion County, West Virginia.—Farther down the stream (Tygart's Valley River) the following structure (Fig. 97) was observed on the right bank, below Nuzum's Mill, Marion County, West Virginia:

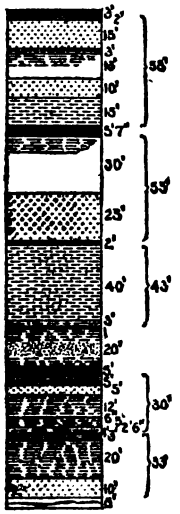

FIG. 97.—Section near Nuzum's Mill, Marion County, W. Va.

Near Nuzum's Mill, Marion County, West Virginia.

[See map, N l.]

		Ft.	in.	Ft.	in.
1.	Coal, Upper Freeport			3	
2.	Clay	2			
3.	Sandstone	15			
4.	Limestone, Upper Freeport	3		58	
5.	Shales and concealed	13			
6.	Sandstone, coarse	10			
7.	Shales, sandy, drab	15			
8.	Coal, Lower Freeport			5	7
9.	Shales and concealed	30		55	
10.	Massive sandstone, Freeport	25			
11.	Coal, Upper Kittanning			2	
12.	Shales, dark, sandy, with limy beds	40		43	
13.	Black slate	3			
14.	Coal, slaty, Middle Kittanning			1	
15.	Shales and sandy beds			20	
16.	Coal, Lower Kittanning			5	
17.	Fire clay	5			
18.	Sandstone, flaggy	5			
19.	Dark shales with iron ore nodules	12		30	
20.	Iron ore, Ferriferous limestone horizon	0	6		
21.	Dark shales	5			
22.	Black slate	2	6		
23.	Coal, Clarion			0	1
24.	Fire clay, sandy	3		33	
25.	Dark shales, with iron ore nuggets near middle	20			
26.	Flaggy sandstone	10			
27.	Concealed and coal blossom, Brookville			6	
28.	No. XII, conglomerate.				
	Total			261	8

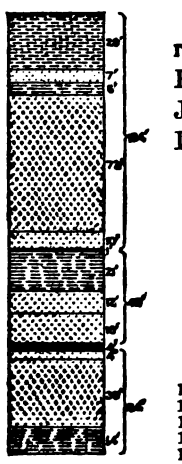

FIG. 98.—Section under Clarksburg, W. Va.

Section under Clarksburg, West Virginia.—From the records of the Despard gas well boring, at Clarksburg, Harrison County, West Virginia, as furnished by T. M. Jackson, civil engineer, we get the structure of the Lower Coal Measures there, as follows (Fig. 98):

Under Clarksburg, West Virginia.

[See map, O k.]

		Ft.	Ft.
1.	Upper Freeport coal		absent
2.	Shales, sandy	29	
3.	Sandstone, white	7	
4.	Shales	6	124
5.	Sandstone, white, Freeport	72	
6.	Sandstone, dark	10	
7.	Coal, Middle Kittanning		1
8.	Shale, black	21	
9.	Sandstone, gray	12	49
10.	Sandstone, white	16	
11.	Coal, with slate, Lower Kittanning		4
12.	Sandstone, hard, gray	4	
13.	Sandstone, hard, white	36	54
14.	Shale	14	
15.	Top of No. XII, white sandstone.		
	Total		232

The Lower Kittanning bed is here more than 1,000 feet below the summits of the hills.

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Section under Parkersburg, West Virginia.—At Parkersburg, Wood County, West Virginia, the following structure (Fig. 99) is given by the record of the Camden Consolidated Oil Company's drill hole, on the authority of R. A. Cole, superintendent:

FIG. 99.—Section under Parkersburg, W. Va.

Under Parkersburg, West Virginia.

[See map, N f.]	Ft.
1. Upper Freeport coal	absent
2. Shales, gray and black	170
3. Coal, Lower Kittanning	7
4. Shales, gray	96
5. Top of No. XII.	
Total	273

The Lower Kittanning bed is the only one in the series here, but it has a good thickness, though lying 1,100 feet below the bed of the Ohio River, and 1,500 feet under the surface of the hill summits.

Section under Wheeling, West Virginia.—Under Wheeling, West Virginia, where the top of the series is more than 400 feet below water level, the record of the Central Glass Company's drill hole for gas gives the following structure (Fig. 100):

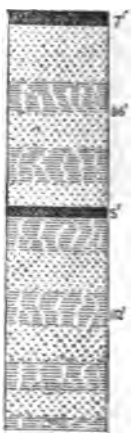

FIG. 100.—Section under Wheeling, W. Va.

Under Wheeling, West Virginia.

[See map, K j.]	Ft.
1. Coal, Upper Freeport—556 feet under Pittsburg coal and 450 feet under Ohio River level	7
2. Sandstone and shales	96
3. Coal, Upper Kittanning	5
4. Shales and sandstone	112
5. Top of No. XII.	
Total	220

Section at mouth of Little Beaver, on the Pennsylvania-Ohio State line.—At the mouth of Little Beaver, on the Pennsylvania-Ohio State line, and the northern point of the West Virginia "Pan-Handle," the structure is as follows (Fig. 101):

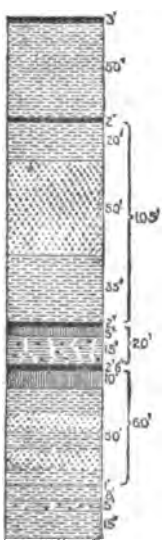

FIG. 101.—Section at mouth of Little Beaver.

Ohio and Pennsylvania line, mouth of Little Beaver.

[See map, G j.]	Ft.	Ft.	in.
1. Coal, Upper Freeport		3	
2. Sandy shales		50	
3. Coal, Lower Freeport		2	
4. Sandy shales	20		
5. Sandstone, massive	50	105	
6. Sandy shales	35		
7. Coal, Middle Kittanning		2	
8. Fire clay	5		
9. Shales, containing nodules of iron ore	15	20	
10. Coal, Lower Kittanning		2	6
11. Fire clay	10		
12. Sandy shales and shaly sandstone	50	60	
13. Limestone, Ferriferous		1	
14. Sandy shales		8	
15. Bituminous shale, Clarion coal		5	
16. Shales, sandy		15	
17. Massive sandstone, top of No. XII.			
Total		273	6

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Section near Sprucevale, Columbiana County, Ohio.—Northward up the Little Beaver the column of rocks is very much the same as at the Ohio River, as may be seen from the following section (Fig. 102) taken near Sprucevale, Columbiana County, Ohio:

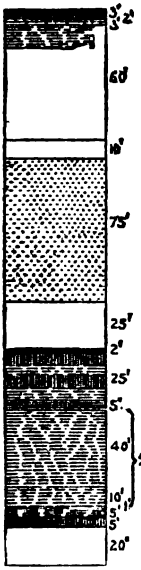

FIG. 102.—Section near Sprucevale, Columbiana County, Ohio.

Near Sprucevale, Columbiana County, Ohio.

[See map, G j.]

		Ft.	Ft.
1.	Coal, Upper Freeport		3
2.	Fire clay		2
3.	Limestone, Upper Freeport		3
4.	Shales, and concealed		60
5.	Coal, Lower Freeport	blossom	
6.	Concealed		10
7.	Sandstone, massive, Freeport		75
8.	Coal, Middle Kittanning	thin	
9.	Concealed		25
10.	Coal, Lower Kittanning		2
11.	Fire clay and shales		25
12.	Limestone, siliceous, Upper Ferriferous		5
13.	Shales, gray	40	50
14.	Shales, dark	10	
15.	Limestone { Lower Ferriferous / Putnam Hill }		1
16.	Coaly shales, Clarion		5
17.	Fire clay		5
18.	Concealed, to top of No. XII		20
	Total		291

Here we get the beginning of an important feature in Ohio Lower Coal Measure stratigraphy, viz: a duplication of the Ferriferous limestone. The lower bed, No. 15, occupies the regular horizon of the Pennsylvania "Ferriferous" bed, but there comes in above it here a stratum, No. 12, of siliceous limestone, not seen anywhere in Pennsylvania, but becoming the ore-bearing limestone of the Ohio series, and known as the "Gray" limestone, the ore on its top being of the same character as the Buhrstone ore of Pennsylvania and apparently identical with it.

Prof. Orton, director of the Ohio Geological Survey, thinks that on entering Ohio the Great Ferriferous limestone of Pennsylvania splits into two portions, the upper part representing the "Gray" limestone and the lower or blue portion of the Ferriferous representing the "Putnam Hill" bed of Ohio. This seems to be the most probable view of the matter, though it is barely possible that the lower or Putnam Hill stratum is an entirely new deposit, and has no representative in Pennsylvania, or this may be true with reference to the upper limestone, No. 12.

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Section between New Lisbon and Leetonia, Ohio.—In going northwestward from Sprucevale, a very rapid change takes place in the lower portion of the column, since it rapidly contracts, as will be seen from the following section (Fig. 103), made in the vicinity of the cement works, between New Lisbon and Leetonia, Ohio:

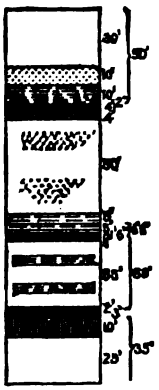

FIG. 103.—Section between New Lisbon and Leetonia, Ohio.

Between New Lisbon and Leetonia, Ohio.

[See map, G i.]	Ft.	Ft.	in.
1. Coal, Upper Freeport (not seen)			
2. Concealed	30	50	
3. Sandstone	10		
4. Shales, chocolate	10		
5. Coal, Lower Freeport		0	2
6. Fire clay		4	
7. Limestone, Lower Freeport		4	
8. Concealed, and sandstone		50	
9. Shales		5	
10. Coal, Lower Kittanning: Cannel slate 5′ 0″; Coal 1′ 6″		6	6
11. Slate	1	39	
12. Limestone and iron ore, Upper Ferriferous	1		
13. Concealed, and shales	35		
14. Limestone, fossiliferous: Lower Ferriferous; Putnam Hill	2		
15. Coal, Clarion		3	
16. Fire clay	10	35	
17. Interval to top of No. XII	25		
Total		196	8

Section near Zanesville, Ohio.—In the vicinity of Zanesville, Muskingum County, Ohio, the section of the Lower Coal Measures reads as follows (Fig. 104), at the type locality of the Putnam Hill limestone (Vol. V, Ohio Geology, p. 96):

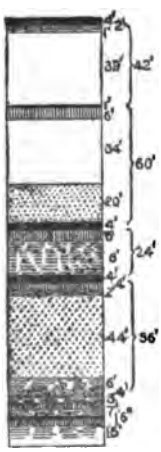

FIG. 104.—Section near Zanesville, Ohio.

Zanesville, Muskingum County, Ohio.

[See map, K e.]	Ft.	Ft.	in.
1. Coal, Upper Freeport		4	
2. Fire clay	2	42	
3. Limestone, Upper Freeport	1		
4. Concealed	39		
5. Coal, Lower Freeport		1	
6. Fire clay	6	60	
7. Concealed	34		
8. Sandstone, Freeport	20		
9. Coal, Middle Kittanning		4	
10. Fire clay	6	24	
11. Shales, with ore nodules	18		
12. Coal, Lower Kittanning		4	
13. Fire clay	4	56	
14. Limestone, Upper Ferriferous	2		
15. Sandstone	44		
16. Shales	6		
17. Limestone: Lower Ferriferous; Putnam Hill		4	
18. Shales, dark		3	
19. Coal	thin		
20. Fire clay and dark shales		7	
21. Coal, Clarion		1	6
22. Fire clay, shales, and concealed, to base of Lower Coal Measures		15	
Total		225	6

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Section near Shawnee and McCuneville, Ohio.—In the vicinity of Shawnee and McCuneville, Perry County, Ohio, these beds exhibit the following structure (Fig. 105):

Vicinity of Shawnee and McCuneville, Perry County, Ohio.

[See map, M d.]

		Ft.	in.
1. Coal, Upper Freeport (not seen)			
2. Fire clay and shales containing "Buchtel" ore		15	
3. Limestone, Upper Freeport		2	6
4. Shales, and concealed		25	
5. Coal, Lower Freeport		1	6
6. Clay, with iron ore		10	
7. Concealed, and shales		25	
8. Coal, Middle Kittanning	Coal 2′ 0″; "Mother" coal 0′ 4″; Coal 4′ 0″; Bony coal 0′ 6″; Slate, dark gray 0′ 3″; Coal 1′ 6″; Slate 0′ 1″; Coal 3′ 0″	10	8
9. Clay, with calcareous ore		10	
10. Concealed, and shales		20	
11. Coal, Lower Kittanning			
12. Clay		5	
13. Ferriferous ore and flint		1	
14. Sandy shales		40	
15. Limestone	Lower Ferriferous; Putnam Hill	1	
16. Fire clay		10	
17. Massive sandstone, top of No. XII.			
Total		176	8

FIG. 105.—Vicinity of Shawnee and McCuneville, Perry County, Ohio.

Section near Buchtel, Ohio.—In the vicinity of Buchtel, at the line of Hocking and Athens Counties, the Lower Coal Measures exhibit this structure (Fig. 106):

Hocking Valley, near Buchtel, Athens County, Ohio.

[See map, N c.]

		Ft.	Ft.	in.
1. Coal, Upper Freeport	Coal, slaty 1′ 3″; Shale 0′ 3″; Coal 1′ 3″; Shale 0′ 3″; Coal 1′ 3″; Shale 0′ 3″; Coal 1′ 3″		5	9
2. Fire clay and shale		5		
3. Limestone, Freeport		5	50	
4. Concealed, and shales		40		
5. Coal, Lower Freeport	Coal 1′ 6″; Slate 0′ 1″; Coal 1′ 6″		3	1
6. Concealed			30	
7. Coal, Middle Kittanning	Bone coal 0′ 6″; Coal 2′ 0″; Slate 0′ 3″; Coal 1′ 9″; Slate 0′ 1″; Coal 1′ 6″		6	1
8. Concealed			30	
9. Coal, Lower Kittanning			1	
10. Concealed			10	
11. Iron ore			1	
12. Limestone, Ferriferous			2	
13. Interval to top of No. XII			40	
Total			178	11

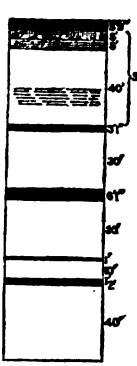

FIG. 106.—Hocking Valley, near Buchtel, Athens County, Ohio.

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Section on Meeker's Run, near Nelsonville, Ohio.—On Meeker's Run, near Nelsonville, Athens County, Ohio, the structure of the Lower Coal Measures is thus (Fig. 107) given by Prof. Orton in Vol. III, Ohio Geology, page 926:

On Meeker's Run, near Nelsonville, Athens County, Ohio.

[See map, N c.]

		Ft.	in.
1.	Coal, Upper Freeport	4	
2.	Fire clay	3	
3.	Shales	5	9
4.	Buchtel ore	1	3
5.	Shales	6	
6.	Straitsville ore	1	
7.	Shawnee or Buff limestone (Upper Freeport)	2	6
8.	Sandstone	14	6
9.	Coal, Lower Freeport	1	0
10.	Shales	4	6
11.	Limestone, Lower Freeport { Ore 0′ 6″; Limestone 1′ 0″ }	1	6
12.	Sandstone	12	6
13.	Coal, Upper Kittanning	3	
14.	Fire clay	1	6
15.	Sandstone	15	6
16.	Shale	3	6
17.	Coal { Middle Kittanning; Nelsonville seam }	6	11
18.	Fire clay	3	
19.	Shale	5	
20.	Snowfork ore	0	8
21.	Sandstone	27	
22.	Coal, Lower Kittanning	2	
23.	Fire clay	4	
24.	Shales	6	
25.	Place for Baird ore		
26.	Place for Gray limestone		
27.	Interval to No. XII sandstone	30	
	Total	165	1

FIG 107.—Section on Meeker's Run, Athens County, Ohio.

Section at Panther Hill, Scioto County, Ohio.—Farther to the southwest, in Panther Hill, near Mt. Vernon Furnace, Scioto County, Ohio, these rocks are given as follows (Fig. 108) in Vol. V, Ohio Geology, p. 1038:

Panther Hill, Mt. Vernon Furnace, Scioto County, Ohio.

[See map, Q a.]

		Feet.	Feet.
1.	Coal, blossom, Upper Freeport		
2.	Shale, sandy	11	38
3.	Concealed	15	
4.	Sandstone, shaly	12	
5.	Coal, blossom, Lower Freeport		
6.	Fire clay	7	39
7.	Shale	8	
8.	Sandstone	20	
9.	Slate	4	
10.	Coal, Middle Kittanning		
11.	Shales, with iron ore (kidney)	16	45
12.	Sandstone, massive	29	
13.	Coal, Lower Kittanning { Coal blossom; Sandstone, shaly 7; Coal blossom }		7
14.	Concealed	8	18
15.	Sandstone, white	6	
16.	Shale	4	
17.	Iron ore, "Baird," buhrstone		
18.	Limestone, Ferriferous		6
19.	Coal	blossom	
20.	Sandstone, white		6
21.	Coal, Clarion		
22.	Shale		16
23.	Coal, Brookville	blossom	
24.	Sandstone, top of No. XII.		
	Total		175

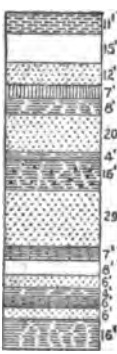

FIG. 108.—Panther Hill, Mt. Vernon Furnace, Scioto County, Ohio.

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Section near Ironton, Ohio.—From the vicinity of Ironton, Ohio, Prof. Orton reports the following structure (Fig. 109) for the Lower Coal Measures (Vol. III, Ohio Geology, p. 928):

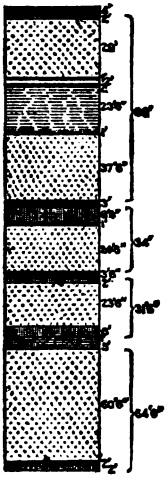

FIG. 109.—Section near Ironton, Ohio.

Ironton, Lawrence County, Ohio.

[See map, R b.]

	Ft.	in.	Ft.	in.
1. Coal, Upper Freeport			4	
2. Fire clay	2			
3. Conglomerate and sandstone	29			
4. Little yellow kidney or Monitor furnace ore	1			
5. Concealed	2			
6. Buff limestone	2		98	
7. Shales	23	6		
8. Yellow kidney ore (Moxahala)	1			
9. Heavy sand rock	37	6		
10. Coal No. 6 (Sheridan coal), Middle Kittanning			3	
11. Fire clay	8	6		
12. Black kidney ore	1		34	
13. Sand rock	24	6		
14. Coal No. V (New Castle), Lower Kittanning			3	6
15. Fire clay	2			
16. Sand rock	23	6	31	6
17. Fire clay	6			
18. Limestone ore			1	
19. Gray limestone, Ferriferous			5	
20. Sand rock, Hearthstone quarries	60	6		
21. Conway coal No. 3, C. (Brookville)	2		64	6
22. Fire clay	2			
23. Top of No. XII, sandstone.				
Total			244	6

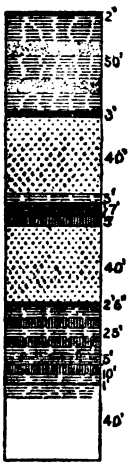

FIG. 110.—Section in southern Ohio, near Ironton.

Section in southern Ohio, near Ironton.—In the same region of Ironton, but at a different locality, the writer found the following structure (Fig. 110):

In southern Ohio, above Ironton.

[See map, S b.]

	Ft.	Ft.	in.
1. Coal, Upper Freeport		2	
2. Shales and sandy beds		50	
3. Coal, Lower Freeport		3	
4. Massive sandstone	40	45	
5. Shale	5		
6. Coal, Middle Kittanning: Coal 1′; Fire clay 1′; Coal 1′; Fire clay 2′; Coal 2′		7	
7. Fire clay	5	45	
8. Sandstone, massive	40		
9. Coal, Lower Kittanning		2	6
10. Shales and fire clay		25	
11. Limestone, Ferriferous		5	
12. Fire clay and shales		10	
13. Coal, Clarion		1	
14. Shales, and concealed		40	
15. Massive sandstone, top of No. XII.			
Total		235	6

This section differs but little from that found in western Pennsylvania. The "Buhrstone" or "Baird" ore, which was not noted in this, is present in other sections at its proper horizon on top of No. 11. The Putnam Hill, or lower division of the Ferriferous limestone, seems to have disappeared, either by coalescing with the upper one or failure of deposition, and the same appears to be true of the Upper Kittanning coal, unless it is to be found in the upper layers of the complex Middle Kittanning No. 6, which is not improbable.

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Section at Charleston, West Virginia.—As we leave the northwestern margin of the Appalachian field in southern Ohio, and pass southeastward toward the other or eastern side of the same, the Lower Coal Measures thicken up quite rapidly, as will be seen from the line of sections which will now be given along the Great Kanawha River. The following one (Fig. 111), from the mouth of Elk River, at Charleston, is the record of Edwards gas well No. 3. It begins at the level of the Upper Freeport coal, and the record was obtained from Mr. W. S. Edwards, the superintendent of the gas company:

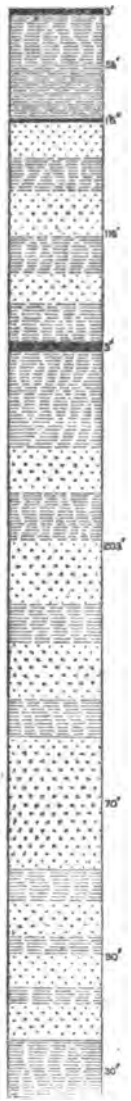

FIG. 111.—Section under Charleston, W. Va.

Under Charleston, Kanawha County, West Virginia, by bore hole near mouth of Elk River.

[See map, S f.]

	Ft.	in.
1. Coal, Upper Freeport	3	
2. Shales and slates	55	
3. Coal, Lower Freeport	1	6
4. Sandstone and shales	116	
5. Coal, slaty, Upper Kittanning	5	
6. Shales and sandstone	233	
7. Sandstone, coarse, with gas and water	70	
8. Coal, Clarion		
9. Shales and sandstone	90	
10. Shales	30	
11. Top of No. XII, white sandstone.		
Total	573	6

The thickness of the measures is here about three times greater than in the Hocking Valley, 100 miles north from Charleston. Just where this rapid thickening begins has not yet been determined, owing to the absence of reliable borings between the Hocking Valley and Charleston, but it is probable that the most of it comes in from the Ohio River southward to Charleston, since the borings at Pomeroy and Hartford City disclose no unusual thickness of the Lower Coal Measures.

The identification of coal No. 8 in the above section is open to question, as it may possibly represent the Lower Kittanning bed.

There may have been other beds of coal passed through by the drill in the well from which this section is taken, since it is seldom that drillers for oil and gas exercise much care in examining the drillings for coal.

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Section at mouth of Lick Run, near Charleston, West Virginia.—Near the mouth of Lick Run, 2 miles south of Charleston, a well was bored for gas, by Mr Hulings, and from the superintendent, Colonel Jordan, I obtained the following record (Fig. 112) by combining it with the 70 odd feet of rocks exposed above the mouth of the boring:

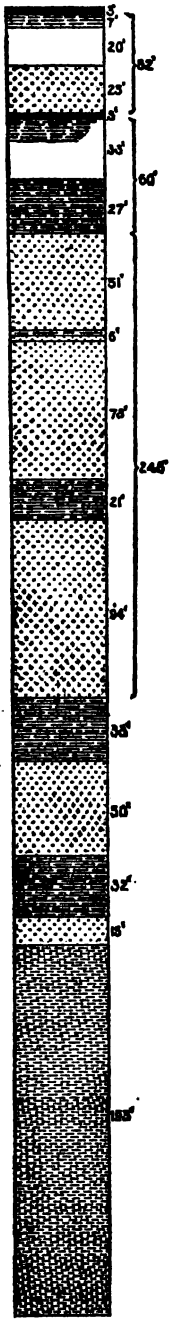

Fig. 112.—At mouth of Lick Run, two miles above Charleston, W. Va.

At mouth of Lick Run, two miles above Charleston, Kanawha County, West Virginia.

[See map, T f.]

		Feet.	Feet.
1. Coal, Upper Freeport			3
2. Shales		7	52
3. Concealed		20	
4. Sandstone, massive		25	
5. Coal, Lower Freeport			3
6. Shales and concealed		33	60
7. Blue slate		27	
8. Sandstone, Freeport	Blue sandstone, hard .. 51′ Slate and sandstone ... 6′ Sandstone, hard ..... 73′ Slate ..... 21′ Sandstone, hard ..... 94′		245
9. Slate, blue			33
10. Sandstone			50
11. Slate			32
12. Sandstone, white			15
13. Sandy shale, dark blue			195
14. White pebbly sandstone, top of No. XII.			
Total			688

Colonel Jordan states that no particular search was made for coal here, and hence several beds may have been passed unnoticed. It is also possible that the top of No. XII is placed about 100 feet too low by the section above, since the ordinary driller frequently neglects to note changes in the character of the strata through which the drill passes; hence it is quite probable that a considerable thickness of No. 13, which the drillers called "sandy shale," may have been really the top portion of the No. XII series.

The Freeport sandstone, No. 8, exhibits an unusual development here, and it is possible that the lowest division included in No. 8 is not really a member of this stratum, but belongs lower in the series.

No. 10 is probably a representative of the Kittanning sandstone.

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Section at Dickinson salt works, Kanawha County, West Virginia.—In the vicinity of Malden, 6 miles above Charleston, the rapid rise of the strata on the northwestern slope of the Brownstown anticlinal has brought nearly all of the Lower Coal Measures to the surface, and the rest of the column is supplied from the records of the Edwards gas well No. 2, at the Dickinson salt works. The combined section reads as follows (Fig. 113):

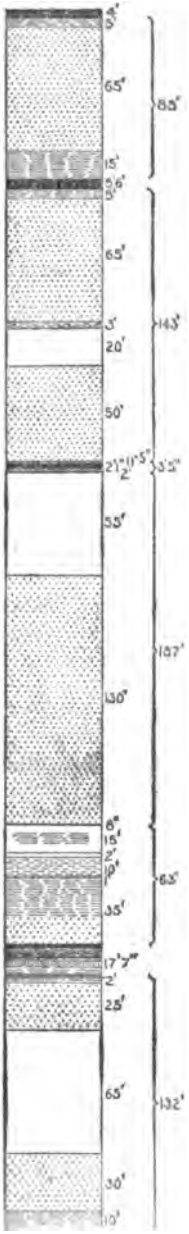

FIG. 113.—Section at Dickinson salt works, Kanawha County, W. Va.

Dickinson salt works, Kanawha County, West Virginia.

			Ft.	Ft.	in.
[See map, T f.]					
1. Coal, Upper Freeport, slaty				4	
2. Shales			5		
3. Sandstone, massive			65	85	
4. Shales			15		
5. Coal, Lower Freeport	Coal, slaty	1' 6"			
	Rock	0' 6"			
	Coal	1' 6"		5	6
	Shale	0' 6"			
	Coal, slaty	1' 6"			
6. Shales			5		
7. Sandstone, massive			65		
8. Sandy shales, with iron ore nodules			3	143	
9. Concealed			20		
10. Sandstone, massive			50		
11. Coal, Upper Kittanning	Coal, slaty	0' 5"			
	Slate, black	0' 11"		3	5
	Coal	2' 1"			
12. Fire clay, sandy			2		
13. Concealed			55	187	
14. Sandstone, massive			130		
15. Coal	Cedar Grove; Middle Kittanning			0	8
16. Concealed, and shales			15		
17. Sandstone			2		
18. Sandy shales			10	63	
19. Limestone, siliceous, Campbell's Creek			1		
20. Shales and sandstone			35		
21. Coal, Campbell's Creek, Lower Kittanning	Coal	2' 0"			
	Shales	1' 2"			
	Coal	0' 4"			
	Fire clay and shales	1' 10"			
	Coal and slate	0' 8"			
	Coal	0' 10"		17	7
	Slate	0' 2"			
	Coal	1' 8"			
	Fire clay and shales	7' 0"			
	Coal, slaty	0' 6"			
	Fire clay	1' 2"			
	Coal	0' 3"			
22. Shales			2		
23. Sandstone, massive			25		
24. Concealed in bore hole			65	132	
25. Sandstone, white			30		
26. Shales			10		
27. White sandstone, top of No. XII.					
Total				641	2

This section would seem to confirm the statement made in connection with the Lick Run boring, viz, that a part of the last interval given there should more properly be credited to No. XII, the next series below the Lower Coal Measures.

The Campbell's Creek, or Lower Kittanning coal, is here very much split up with slate and shales, but on the Malden side of the Kanawha it is a good bed, from which 4 to 6 feet of coal is obtained with only the two parting slates.

This is the type locality of the Campbell's Creek limestone No. 19.

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Section near Brownstown, West Virginia.—In the vicinity of Brownstown and near the Burning Spring, 9 miles above Charleston, another gas well was drilled (Edwards No. 1) and its record combined with the surface exposures in that vicinity gives the following succession (Fig. 114):

Near Brownstown, three miles south from Malden.

[See map, T f.]

		Ft.	in.	Ft.	in.
1.	Coal, Upper Freeport, slaty			5	
2.	Concealed	10			
3.	Sandstone, massive, gray	95			
4.	Shales, and concealed	30			
5.	Sandstone, massive, gray	40		375	
6.	Sandy shales, and concealed	25			
7.	Sandstone, gray, micaceous	160			
8.	Concealed	15			
9.	Coal (Cedar Grove), Middle Kittanning			3	4
10.	Concealed, and sandstone			100	
12.	Coal. Lower Kittanning, Campbell's Creek. Coal	2′	6″		
	Shales and sandstone	20′	0″	24	10
	Coal	2′	4″		
13.	Shales	3			
14.	Sandstone, massive	25			
15.	Concealed	5		74	
16.	Coaly shale	1			
17.	Fire clay, sandstone, and concealed	40			
18.	Coal, Brownstown			2	
19.	Shales	5			
20.	Sandstone, massive	30		70	
21.	Sandy shales and flaggy sandstone	35			
22.	Limestone, siliceous, Ferriferous			1	
23	Shales, sandy	15			
24.	Slate, black	0	6	45	6
25.	Shales	7			
26.	Sandstone, and concealed	23			
27.	Coal, Clarion (Eagle)			3	
28.	Sandstone	25			
29.	Slate, gray	8		98	
30.	Sandstone, gray	40			
31.	Slate, dark	25			
32.	White sandstone, top of No. XII.				
	Total			801	8

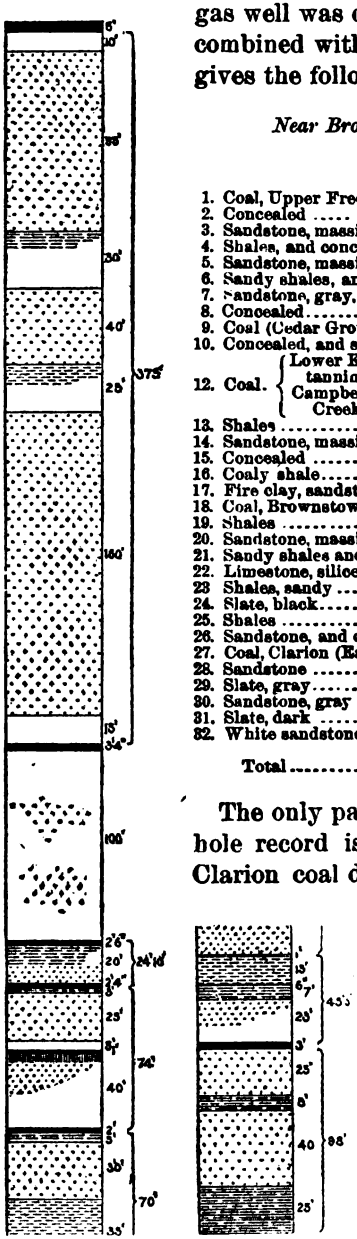

FIG. 114.—Section near Brownstown, three miles south from Malden, W. Va.

The only part of this series dependent on the bore hole record is the last 100 feet, or that from the Clarion coal down, the rest of it all being exposed above the bed of the Kanawha in the region of Brownstown.

By comparing this with the Charleston section (Fig. 111) it will be seen that the whole column has thickened southward at the rate of about 25 feet to the mile. It will also be observed that with this thickening a new coal, the Brownstown, makes its appearance in the series. This is one of a local group of two or three coals which appear in the column of rocks around the southeastern margin of the coal field between the Lower Kittanning bed and the Ferriferous limestone, which would seem to be represented by No. 22 of the section. These coals are of little economic importance, as they are usually thin and slaty.

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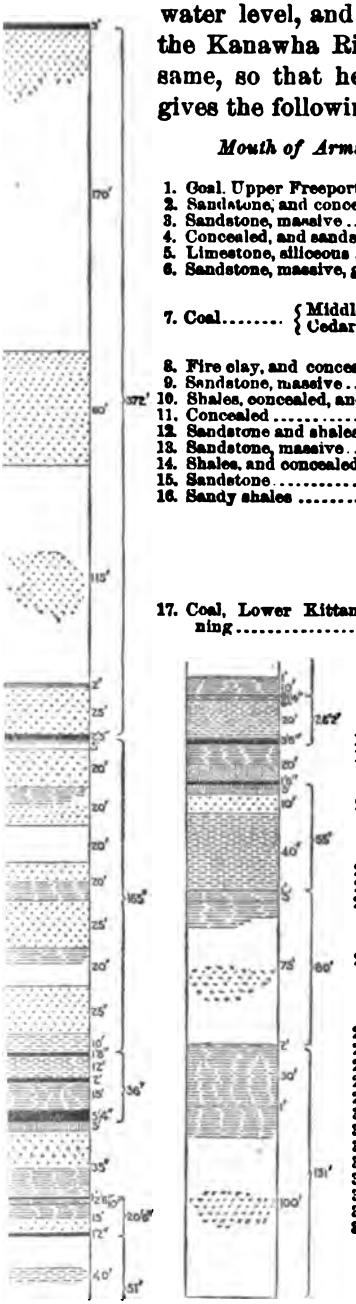
ection at mouth of Armstrong Creek, on the Big Kanawha River, West ·ginia.—At the mouth of Armstrong Creek, 25 miles south from arleston, the whole column of the Lower Coal Measures is above water level, and a high point almost vertically above the Kanawha River catches the top members of the same, so that here a very fine exposure of the series gives the following structure (Fig. 115):



115.—Section at mouth of Armstrong Creek, on the Big Kanawha River.

Mouth of Armstrong Creek, on the Big Kanawha River.

[See map, U g.]

		Ft.	Ft. in.
1. Coal. Upper Freeport			3
2. Sandstone, and concealed		170	
3. Sandstone, massive		60	
4. Concealed, and sandstone		115	372
5. Limestone, siliceous		2	
6. Sandstone, massive, gray		25	
7. Coal: Middle Kittanning. Cedar Grove	Coal 6″; Shale 8″; Coal 5′ 6″; Shale 6″; Coal 4″		2 5
8. Fire clay, and concealed		5	
9. Sandstone, massive		20	
10. Shales, concealed, and sandstone		20	
11. Concealed		20	
12. Sandstone and shales		20	165
13. Sandstone, massive		25	
14. Shales, and concealed		20	
15. Sandstone		25	
16. Sandy shales		10	
17. Coal, Lower Kittanning	Coal 1′ 1″; Slate 0′ 1″; Coal 0′ 6″ (1′ 8″); Sandy shales 12′ 0″; Coal, "Peerless" 2′ 0″; Shales, bluish 15′ 0″; Coal, sulphurous 0′ 5″; Slate 0′ ¼″; Coal 0′ 6″; Coal, splint 0′ 11″; Parting 0′ ½″; Coal 0′ 7″; Slate 0′ ½″; Coal 2′ 10″		36
18. Fire clay			5
19. Sandstone and shales			35
20. Coal, Brownstown	Coal 1′ 0″; Shale 2′ 6″; Coal 0′ 10″; Shales and sandstone 15′ 0″; Coal 1′ 2″		20 6
21. Concealed, and sandy shales		40	
22. Limestone, siliceous, Ferriferous		1	51
23. Shales		10	
24. Coal, Clarion (Eagle)	Coal 0′ 8″; Shales 1′ 4″; Coal, slaty 0′ 6″; Shales, sandy 20′ 0″; Coal 0′ 2″; Shales 0′ 8″; Coal 2′ 10″		26 2
25. Shales and sandy beds			20
26. Coal, Little Eagle			1 6
27. Fire clay and shales		5	
28. Sandstone, massive		10	55
29. Shales, sandy		40	
30. Limestone, fossiliferous, Eagle			1
31. Dark shales, fossiliferous		5	80
32. Shales, sandstones, and concealed		75	
33. Bituminous shale			2
34. Shales		30	
35. Limestone, siliceous		1	131
36. Shales, sandstone, and concealed		100	
37. Sandstone, massive, top of No. XII.			
Total		1,006	7

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Here both the Lower Kittanning and the Clarion coals show in their structure the effect of the general thickening up of the whole column of rocks. Three miles north from this, the Clarion or Eagle coal is a good bed, which, with its partings of slate, is only 4½ feet thick, but the partings gradually thicken and new ones come in till the structure shown in No. 24 is obtained.

A small coal which has been termed the Little Eagle comes into the section in this region, and seems to have a wide distribution around the southern margin of the coal field. It is a very pure coal and may be a lower member of the Clarion bed.

The Eagle limestone, No. 30, was named from a mining village 3 miles below the locality of this section, where it is finely exposed in the cuts of the Chesapeake and Ohio Railroad. It and the shales below it are crowded with the Lower Coal Measures fossils, the general facies of the fauna being very similar to that found in connection with the Ferriferous limestone in western Pennsylvania, but the general section forbids the supposition that it is identical with the latter. At one time I entertained the idea that it might be the representative of the Putnam Hill limestone, of Ohio, but a closer study of the Ohio section renders that hypothesis untenable, since the Putnam Hill bed belongs above the Clarion coal and not below, as does the Eagle limestone.

No. 33 is a very bituminous shale, since lubricating oil was once manufactured therefrom, and it may possibly represent the Brookville coal of Pennsylvania.

A comparison of this section with those on the other side of the Appalachian basin at Buchtel (106) and Shawnee (105) will show the wonderful expansion of these beds from 175 feet at the latter localities to a thickness of more than 1,000 feet at Armstrong's Creek, and the same thing is shown graphically in map, Section C. That such a great expansion of these measures should show only the same number of workable coal beds as the section at Shawnee was hardly to be expected, but it is true beyond question. The coal beds themselves give evidence of this great expansion of the general column in the slates and other impurities with which they are interstratified.

The interval (165 feet) which here separates the Middle and Lower Kittanning coal beds appears excessive, since it is only 100 feet a few miles below, but there can be very little doubt of the figures given, and as there are no coal beds between Nos. 7 and 17, it is evident that No. 7 must be the Middle Kittanning.

The top member of the Pottsville conglomerate is in the bed of the Kanawha, where the section shown in Fig. 115 ends.

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Section at Guyandotte Mountain, Raleigh County, West Virginia.—That the Lower Coal Measures keep their greatly expanded measurement on southwestward from the Kanawha River is shown by the following section (Fig. 116) made by Captain Miller, chief engineer of the Trans-Flat-Top Land Association. It begins at the summit of Guyandotte Mountain, Raleigh County, West Virginia, and was measured along the turnpike eastward to the foot of the mountain:

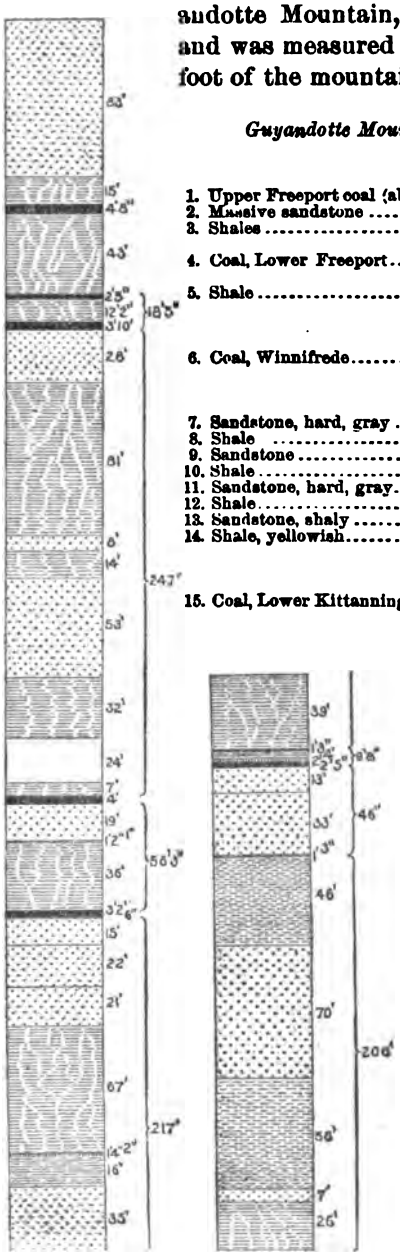

FIG. 116.—Section at Guyandotte Mountain, Raleigh County, W. Va.

Guyandotte Mountain, Raleigh County, West Virginia.

[See map, W g.]	Ft. in.	Ft. in.
1. Upper Freeport coal (absent)		
2. Massive sandstone		83
3. Shales		15
4. Coal, Lower Freeport: Coal 3′ 10″; Slate 0′ 1″; Coal 0′ 9″		4 8
5. Shale		43
6. Coal, Winnifrede: Coal 2′ 5″; Shale 12′ 2″; Coal 1′ 3″; Slate 0′ 2″; Coal 2′ 3″; Slate 0′ 1″; Coal 0′ 1″		18 5
7. Sandstone, hard, gray	28	
8. Shale	81	
9. Sandstone	8	
10. Shale	14	
11. Sandstone, hard, gray	53	247
12. Shale	32	
13. Sandstone, shaly	24	
14. Shale, yellowish	7	
15. Coal, Lower Kittanning: Coal 0′ 7″; Slate 0′ 1″; Coal 0′ 9″; Slate 0′ 0½″; Coal 1′ 1″; Slate 0′ 4″; Coal 1′ 1½″		
16. Sandstone, soft, yellow	19	
17. Coal	0	1
18. Fire clay	1	2 56 3
19. Shales, yellowish	36	
20. Coal, Brownstown: Coal 0′ 1″; Fire clay 2′ 0″; Coal 1′ 1″		3 2
21. Fire clay	0	6
22. Sandstone, soft, yellow	15	
23. Sandstone, hard, gray	22	
24. Sandstone, soft, yellow, micaceous	21	
25. Shales, yellowish	67	
26. Coal	0	2 217
27. Fire clay	1	4
28. Slate, black	16	
29. Sandstone, soft, yellow	35	
30. Shales, yellow	39	
31. Coal, Eagle (Clarion): Coal 1′ 3″; Slate 4′ 0″; Fire clay 2′ 0″; Coal 0′ 1″; Clay 0′ 3″; Coal 0′ 9″; Clay 0′ 2″; Coal 0′ 1″; Clay 1′ 0″; Coal 0′ 1″		9 8
32. Sandstone, hard, gray	13	
33. Sandstone, soft, yellow	33	46
34. Coal, Little Eagle		0 3
35. Fire clay	1	
36. Shales, sandy, yellow	46	
37. Sandstone, soft, yellow	70	208
38. Shales, sandy, yellowish	58	
39. Sandstone, flaggy	7	
40. Shales, yellow	26	
41. Pebbly sandstone, top of No. XII.		
Total		655 5

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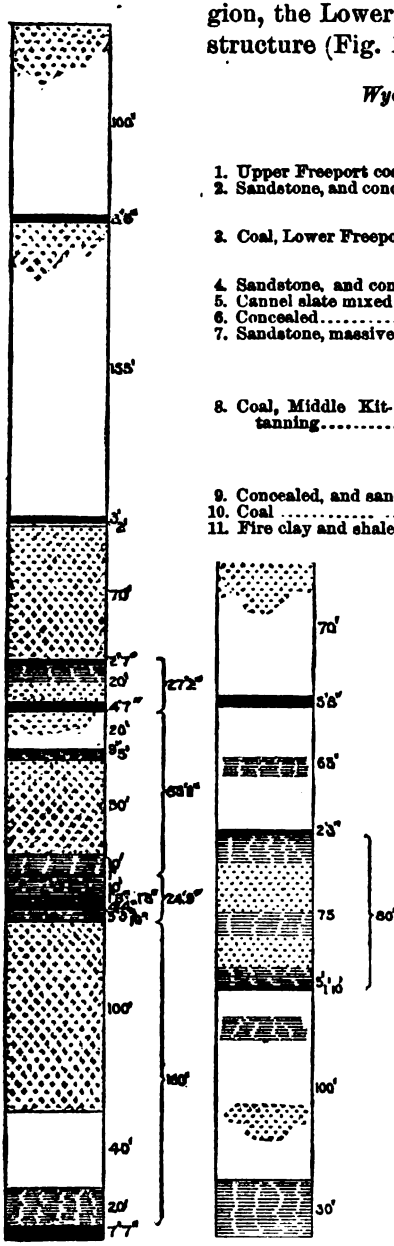
It is possible that the horizon of the Upper Freeport coal should have been placed higher than the section shows, since the coal is not present and the place given it is only a surmise.

Section near Oceana, Wyoming County, West Virginia.—In the vicinity of Oceana, Wyoming County, West Virginia, and the neighboring region, the Lower Coal Measures present the following structure (Fig. 117):



Wyoming County, West Virginia.

[See map, W f.]

		Ft.	in.	Ft.	in.
1. Upper Freeport coal (not seen)					
2. Sandstone, and concealed				100	
3. Coal, Lower Freeport	Coal 0′ 1″; Shale 0′ 4″; Coal 0′ 10″; Bony coal 0′ 4″; Coal 2′ 1″			3	8
4. Sandstone, and concealed				155	
5. Cannel slate mixed with coal, Upper Kittanning				3	
6. Concealed				2	
7. Sandstone, massive				70	
8. Coal, Middle Kittanning	Coal 1′ 6″; Shale 0′ 5″; Coal 0′ 8″	2	7	27	2
	Shales and sandstone	20			
	Coal, good 2′ 6″; Shale, gray 0′ 2½″; Coal 0′ 3½″; Shale, gray 0′ 10″; Coal 0′ 9″	4	7		
9. Concealed, and sandstone		20		85	9
10. Coal		0	9		
11. Fire clay and shales		5			
12. Sandstone, massive		50			
13. Shales, dark, slaty		10			
14. Coal, Lower Kittanning	Coal 1′ 0″; Slate 10′ 0″; Coal 1′ 8″; Slate, dark 0′ 6″; Coal 1′ 2″; Slate 0′ 4″; Coal 4′ 0″; Slate 5′ 3″; Coal 0′ 10″			24	9
15. Massive sandstone		100		160	
16. Concealed		40			
17. Shales		20			
18. Coal, Brownstown	Coal 1′ 7″; Slate 1′ 4″; Coal 0′ 2″; Slate 0′ 8″; Coal 0′ 4″; Slate 0′ 4″; Coal 0′ 6″; Slate 1′ 8″; Coal 1′ 0″			7	7
19. Sandstone, and concealed				70	
20. Coal, Eagle (Clarion)	Coal 3′ 4″; Slate 0′ 4″; Coal 2′ 0″			5	8
21. Concealed, and shales				65	
22. Coal, Little Eagle				2	3
23. Shales and sandstones		75		80	
24. Shales, gray, with fossil plants		5			
25. Coal				1	10
26. Concealed, and shales and sandstone				100	
27. Coal, blossom					
28. Shales				30	
29. Massive sandstones, top of No. XII.					
Total				993	8

FIG. 117.—Section near Oceana, Wyoming County, W. Va.

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No. 20 is known as the "coking coal" in the Wyoming region, since it has the typical structure of such coal, and looks very much like the same (Eagle) bed on the Kanawha.

The Little Eagle bed No. 22 is also very good coal here, and its interval below the main seam has increased from 20 to 65 feet.

Section at mouth of Blaine Creek, Lawrence County, Kentucky.—In passing southward up the Big Sandy River, at the southwestern line of West Virginia, the Lower Coal Measures thicken up at about the same rate as they do along the Kanawha, as will be seen from the following sections. The first one (Fig. 118) is from a surface measurement, combined with the record of Rigdon gas well No. 2, at the mouth of Blaine Creek, 20 miles above the mouth of the Big Sandy River, and reads as follows:

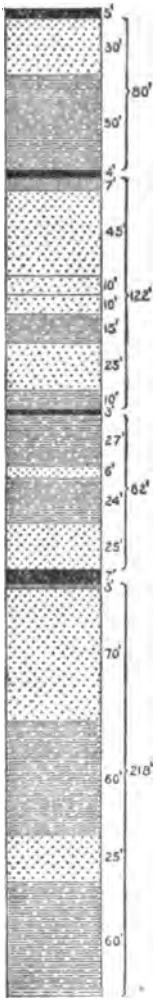

FIG. 118.—Section at mouth of Blaine Creek, Ky.

Mouth of Blaine Creek, twenty miles above mouth of Big Sandy River, Kentucky.

[See map, T b.]

	Feet.	Feet.
1. Coal and black slate, Upper Freeport		5
2. Sandstone	30	80
3. Slate, black	50	
4. Coal, Lower Freeport		4
5. Fire clay	7	122
6. Sandstone, white	45	
7. Sandstone, dark gray	10	
8. Sandstone, white	10	
9. Slate, black	15	
10. Sandstone, dark	25	
11. Slate, black	10	
12. Coal, Middle Kittanning		3
13. Slate	27	62
14. Sandstone, gray	6	
15. Slate, black	24	
16. Sandstone, gray	25	
17. Coal, Lower Kittanning		7
18. Fire clay	3	218
19. Sandstone, gray	70	
20. Slate, gray	60	
21. Sandstone, gray	25	
22. Slate, black	60	
23. Sandstone, white, top of No. XII.		
Total		521

For the carefully kept record of this boring I am indebted to Mr. F. H. Oliphant, now the chief geologist of the South Penn Oil Company.

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Section near Old Peach Orchard, Lawrence County, Kentucky.—In the vicinity of Old Peach Orchard, on the Louisa fork of Big Sandy River, Kentucky, the surface measurements, combined with the records of oil and gas borings near by, give the following structure (Fig. 119):

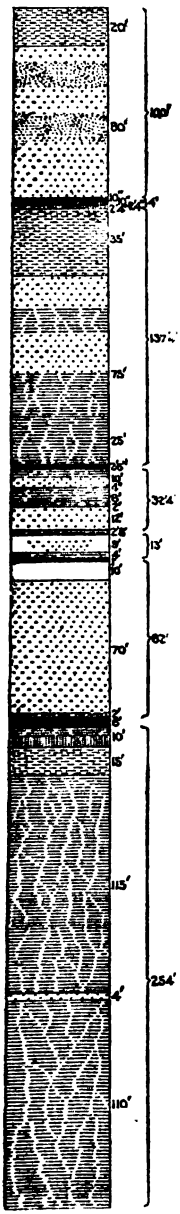

FIG. 119.—Section near Old Peach Orchard, Ky.

Near Peach Orchard, Kentucky.

[See map, V b.]		Ft.	in.	Ft.	in.
1. Upper Freeport coal (absent)					
2. Sandy shales		20		100	
3. Sandstone and sandy beds		80			
4. Coal ... Lower Freeport, or Winnifrede, Peach Orchard bed	Coal ..... 0′ 10″; Shale ..... 0′ 10″; Coal ..... 2′ 4″				
5. Fire clay, siliceous		2	4	137	4
6. Sandy shales		35			
7. Massive sandstone and shaly micaceous beds		75			
8. Blue sandy shales		25			
9. Coal, Upper Kittanning	Cannel ..... 1′ 0″; Clay ..... 0′ 6″; Coal, slaty ..... 1′ 0″			2	6
10. Shale and sandstone		10			
11. Coal		0	4		
12. Sandy shale, blue		8		32	4
13. Limestone		2			
14. Sandstone, shaly		12			
15. Coal	Coal ..... 0′ 6″; Shale ..... 1′ 6″; Coal ..... 0′ 8″			2	8
16. Concealed, and shaly sandstone		9		13	
17. Black slate		4			
18. Coal, splint, Middle Kittanning				1	
19. Concealed		10			
20. Hard sandstone		70		82	
21. Blue shale		2			
22. Coal, Lower Kittanning				6	
23. Shales and fire clay		10			
24. Sandy shale		15			
25. Black shales		115		254	
26. Sandstone		4			
27. Dark shale		110			
28. White sandstone, top of No. XII.					
Total				634	10

The place of the Upper Freeport coal here is determined with comparative certainty by the massive Mahoning sandstones, which come in above No. 1, and also by the occurrence of the Mahoning coal, with its characteristic structure, at 235 feet above the Peach Orchard bed, and 135 feet above where the horizon of the Upper Freeport has been placed.

No. 15 is very probably a "split" from the Middle Kittanning bed, No. 18, and should be regarded as a part of the latter.

The Lower Kittanning bed, No. 22, is given as reported from a bore hole at "Old" Peach Orchard, by Prof. Shumard, who examined the drillings at the time the boring was made, and the rest of the section below this is from a deep boring made for gas, about 3 miles distant, the record of which was obtained from Mr. F. H. Oliphant, the civil engineer under whose superintendence the deep well was bored.

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There has been much variance of opinion among geologists who have examined the Peach Orchard coal bed as to its horizon in the series, some placing it as far down in the column as the Clarion coal, but this section shows that it is either the Lower Freeport coal of the Pennsylvania column or else one that is probably a "split" from the latter, viz, the Winnifrede bed of the Kanawha series.

Section near Warfield, Kentucky.—In the vicinity of Warfield, Kentucky, opposite the line of Logan County, West Virginia, and 60 miles above the mouth of the Big Sandy, the following structure (Fig. 120) is obtained by combining the surface observations with the records of of the Warfield gas wells:

Warfield, Kentucky, on Tug Fork of Big Sandy River.

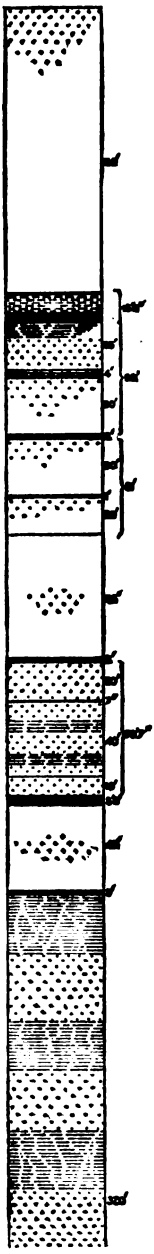
[See map, V b.]

		Ft.	in.	Ft.	in.
1. Upper Freeport coal (not seen)					
2. Massive sandstone, and concealed				150	
3. Coal, Winnifrede	Coal 0′ 5″; Sandy shales 10′ 0″; Fire clay 2′ 0″; Coal, splint 1′ 2″; Clay 0′ 1″; Coal, splint 1′ 4″; Clay 0′ ½″; Coal 0′ 9″			15	9
4. Concealed, and sandstone		25			
5. Limestone, siliceous		4		59	
6. Shales, sandstone, and concealed		30			
7. Coal, cannel, Upper Kittanning				2	
8. Sandstone, and concealed		30			
9. Limestone, siliceous		1		51	
10. Sandstone, and concealed		20			
11. Coal, blossom, Middle Kittanning					
12. Concealed, and sandstone				65	
13. Limestone, siliceous				2	
14. Sandstone, massive		20			
15. Shale		0	3		
16. Coal		0	4	70	7
17. Sandstone and shales		40			
18. Sandstone, massive		10			
19. Coal, Lower Kittanning	Coal 0′ 4″; Shale 6′ 10″; Coal 4′ 0″			5	2
20. Concealed, and sandstone				45	
21. Limestone, siliceous				2	
22. Shales and sandstones to top of No. XII				320	
Total				787	6

Some have supposed that No. 3 of this last section is identical with the Peach Orchard bed, but it seems to occupy a horizon a few feet below the latter, and I have therefore referred it to the Winnifrede bed of the Kanawha column.

No. 19, which is locally known as the "Warfield" coal, is the same one as No. 22 of Section 119, and the representative of the Lower Kittanning bed.

The "siliceous" limestones, Nos. 13 and 21, may possibly represent the Campbell's Creek and Ferriferous beds respectively.



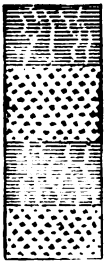


FIG. 120.—Section at Warfield, Ky., on Tug Fork of Big Sandy River.

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Section on Tug Fork of Big Sandy River, Logan County, West Virginia.—Near the mouth of Knox Creek, at the southern edge of Logan County, 50 miles by the river above Warfield, the following section (Fig. 121) was constructed on the West Virginia side of Tug River, by adding to the upper portion of the section there the part which has been removed by erosion:

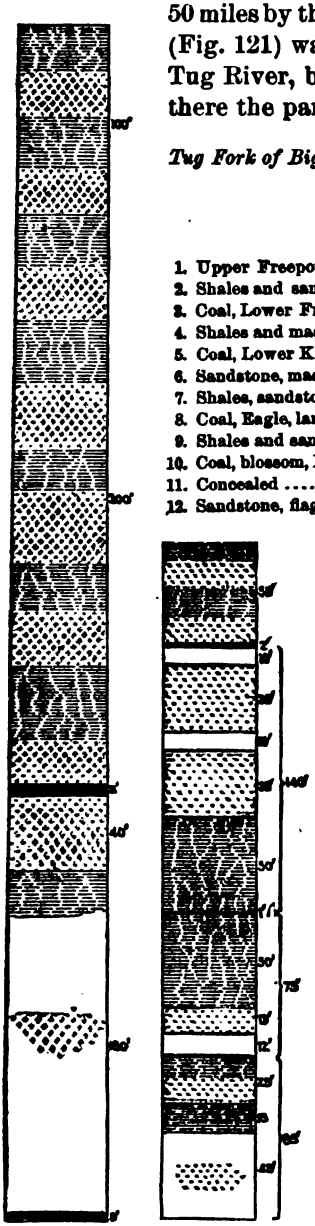

FIG. 121.—Section on Tug Fork of Big Sandy River, near mouth of Knox Creek, southern edge of Logan County, W. Va.

Tug Fork of Big Sandy River, near mouth of Knox Creek, southern edge of Logan County, West Virginia.

[See map, W d.]

	Ft.	Ft.
1. Upper Freeport coal (absent)		
2. Shales and sandstone		100
3. Coal, Lower Freeport		
4. Shales and massive sandstone		300
5. Coal, Lower Kittanning, large blossom		6
6. Sandstone, massive		40
7. Shales, sandstone, and concealed		180
8. Coal, Eagle, large blossom		5
9. Shales and sandstone		55
10. Coal, blossom, Little Eagle		2
11. Concealed	10	
12. Sandstone, flaggy	35	
13. Concealed	10	140
14. Sandstone, gray	35	
15. Shales, soft, gray	50	
16. Limestone, blue, impure (Eagle?)		1
17. Shales, dark blue	50	
18. Sandstone	13	75
19. Concealed	12	
20. Coal		1
21. Shales and flaggy sandstone	25	
22. Slates, dark	15	85
23. Concealed, sandstone, and concealed	45	
24. Massive coarse sandstone, top of No. XII.		
Total		990

CHARACTERISTIC HORIZONS.

THE UPPER FREEPORT COAL.

As may be seen by the sections just given, a very important coal bed comes at the summit of the Lower Coal Measures column, and marks the latter off from the Barrens above. This coal, which was named the Upper Freeport coal by Rogers, has a very wide distribution in the Appalachian field and is the source of much valuable coal and coke. The coal is not entirely persistent, however, being frequently too thin to mine, and from large areas it is absent entirely, though its horizon in the measures can then still be determined, and generally without much difficulty. The bed is probably more regular and persistent in Pennsylvania than

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in either of the other two States (Ohio and West Virginia), but even there it is not always found in workable condition, being thin or wanting in some portions of nearly every county where its outcrop extends.

One of the main features which characterizes this bed is its complexity, since it is always separated into two or more benches by divisions of slate. This complexity of structure is illustrated at the type locality (Section 66), and so far as the writer knows it is never entirely absent anywhere in the Appalachian field, whenever the bed is thick enough to mine. These parting slates vary in both number and thickness in different regions, so that there is nothing characteristic about them over the whole field, but yet in any particular district or coal basin their number and position in the bed are quite regular.

Another peculiarity of the coal is that it nearly always cokes well whenever attaining anything like its normal thickness and hence in several regions is locally known as the "coking vein." There are many districts where this bed will produce coke but little if any inferior to that of the Pittsburgh, in the famous Connellsville basin, and when the latter is exhausted the next source of supply to the Pittsburgh and Pennsylvania region generally must come largely from this horizon. Still another feature of this coal is its tenderness, and by this it can often be distinguished from the very hard Mahoning coal next above (which often rivals this bed in size), since as a rule the coal from the Upper Freeport horizon does not bear much handling without breaking up most of the lumps, although they often come out of the mine with large size. This is true of the bed everywhere in Pennsylvania and West Virginia (except in the southwestern part of the latter State, where it is often a splint coal), and Prof. Orton reports the same thing as characterizing it all over the Ohio field.

There is frequently a layer of impure cannel or highly bituminous slate in the roof of this coal, and in the Great Kanawha region a fine deposit of cannel coal occurs at this horizon. This is true of the Cannelton locality, but whether any of the cannel deposits on Coal River, south from the Kanawha, belong at this same geological level is as yet undetermined, since the latter have not been sufficiently studied, though the flora would indicate that the Peytona deposit belongs at the horizon of the Upper Kittanning coal.

The several sections that have already been given (Nos. 50–121), indicate the structure of the Upper Freeport bed in many regions, but there remain others where it is equally important, and some of these will now be given.

Section at McCoy shaft, near Gallitzin, Cambria County, Pennsylvania.—Some large coke plants have recently been put into operation on this bed along the line of the Pennsylvania Railroad and its branches on the summit of the Alleghany Mountains in Cambria and Clearfield

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Counties. At the McCoy shaft, near Gallitzin, the coal has the following structure, according to the superintendent's statement:

	Ft.	in.	Ft.	in.
Black slate and bone coal	0	8	6	5
Coal	4	0		
Slate, gray	0	2		
Coal	1	0		
Slate	0	3		
Coal	0	4		

Section near eastern end of old Portage Railroad tunnel, at Gallitzin, Pennsylvania.—Near the eastern end of the old Portage Railroad tunnel, at Gallitzin, the coal is well exposed, and there shows as follows:

	Ft.	in.	Ft.	in.
Coal	0	4	5	8
Dark slate and bony coal	0	2		
Coal	3	0		
Slate, gray	0	2		
Coal	1	2		
Slate and slaty coal	0	10		

According to Messrs. Chance and Platt, this coal is but poorly represented in the present mining regions of Clearfield and Jefferson Counties, Pennsylvania, but it is possible, as already suggested in connection with section 88, that in some cases, at least, the Upper Freeport coal may have been erroneously referred to the horizon of the Lower Freeport.

Section at Mount Equity mine, Bedford County, Pennsylvania.—In the Broad Top field this coal is finely developed in Bedford County, where it is known as the "Kelly seam," and exhibits the following structure at the Mt. Equity mine, according to Stevenson, Report T², Second Geological Survey of Pennsylvania, page 62:

	Ft.	in.	Ft.	in.
Coal	2	1	7	2
Parting				
Coal	0	7		
Parting				
Coal	1	2		
Parting				
Coal	1	0		
Clay	2	0		
Coal	0	4		

Although this bed is so well developed in Bedford County, yet when followed northward into Huntingdon, only 10 miles distant, it thins away to only 1 foot or even less.

Followed southward from Cambria County along the Alleghanies, this coal becomes quite thin and slaty in Somerset, and where the bed enters Maryland near the northern end of the Georges Creek basin, it is only 3 to 4 feet thick and quite slaty, there being a layer of bony, worthless coal, 1 foot thick, just above the middle.

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This poor condition of the bed seems to be maintained southward along the Georges Creek basin to Piedmont (Section 92) and up the North Potomac (Section 93) to near its source (Section 94) before the coal becomes valuable again, since there the whole bed thickens up to 8 feet, and is extensively mined at Thomas, on the West Virginia Central Railroad, in spite of the fact that 2 feet of bony, worthless coal still remains near the center of the bed.

In the Ligonier basin of Westmoreland and Fayette Counties, Pennsylvania, Prof. Stevenson reports this bed of inferior quality, being filled with knife edges of slate and containing too much sulphur for the manufacture of coke, though it often has a good thickness. This condition of affairs is continued southward along the Ligonier basin into Preston County, West Virginia, until we begin to approach the vicinity of Cheat River, when a great change takes place in the character of the coal, the sulphur and thin slates disappearing and the whole becoming a most valuable coking coal.

Section at Posten's bank, near Masontown, Preston County, West Virginia.—The section at Mr. Posten's bank, 2 miles from Masontown, Preston County, shows the following structure:

	Ft.	in.	Ft.	in.
Coal, slaty	1	3	9	7
Coal, good	3	0		
Slate, gray	0	3		
Coal, good	1	3		
Shale	0	10		
Coal, good	3	0		

This is near the center of the basin, and the coal is there thicker than the average.

Section at Hartley's bank, near Masontown, Preston County, West Virginia.—The following from the side of the trough near Masontown, at Mr. Hartley's bank, will better represent the average thickness of this coal in the Preston basin:

	Ft.	in.	Ft.	in.
Slaty coal	1	3	8	7
Coal, good	3	5		
Shale, gray	0	2		
Coal, good	1	3		
Shale, gray	1	0		
Coal, good	1	6		

The first parting below the top is usually called the "little" slate, while the next one is known as the "big" slate.

This is the same coal that has long been coked for the manufacture of iron at Irondale, Preston County, and also near Austin, on the Baltimore and Ohio Railroad. At both of these localities the coal below the "big" slate is not taken out on account of the expense of mining the latter.

Southward from the Baltimore and Ohio Railroad this bed again splits up with numerous slate partings, and when it comes out to day-

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light, on the Valley River, at Philippi, the coal is 4 feet thick, but so slaty as to be almost valueless, and only 20 to 25 feet above the Lower Freeport coal.

Section at Wilson's mine, Roaring Creek, Randolph County, West Virginia.—Southward from Philippi it increases in thickness, and when we come to the eastern side of the Belington basin the bed has a total height of 10 to 15 feet, and is locally known as the Roaring Creek vein. Its structure there is shown by the following section at Mr. William Wilson's mine, in the northern edge of Randolph County, and about 1 mile east from the Valley River, at the mouth of Roaring Creek:

	Ft.	in.	
Coal, slaty, impure	1	6	Feet. 14
Shales, dark	2	0	
Coal, "upper bench"	2	8	
Slate and bony coal	1	3	
Coal, "breast"	3	1	
Slate, gray	0	6	
Coal, "mining ply"	1	8	
Clay and slate	0	4	
Coal, "bottom," slaty	1	0	

At some localities the "bottom" and "mining ply" benches form one layer of coal 3 to 4 feet thick, but as a rule the "bottom" portion is slaty and worthless, while the "mining ply" and the "breast" layers furnish very good fuel, the "upper bench" being frequently slaty and otherwise impure.

Followed still farther southward along the eastern side of the Appalachian field, through Randolph, Upshur, Lewis, Webster, Nicholas, Fayette, Kanawha, Lincoln, Cabell, and Wayne Counties, West Virginia, this coal bed presents the features shown in the sections given below.

Section on Stone Coal Run, Upshur County, West Virginia.—In Upshur County, 10 miles west from the Roaring Creek region, the Upper Freeport coal is exposed on Stone Coal Run, a tributary of the Big Sandy, which empties into the Buckhannon River. Here the following structure is visible:

	Ft.	in.		Ft.	in.	
Black slate	2	6	Roof.	14	8	Ft. 22
Coal	1	0				
Bony coal	0	8				
Coal	2	0				
Black slate	3	0				
Coal	1	0				
Gray slate	4	6				
Coal	1	5	Main bench.	7	4	
Slate, dark	1	4				
Coal	1	10				
Slate, dark	0	5				
Coal, slaty	0	5				
Slate, gray	0	6				
Coal	1	5				

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This is the locality of the celebrated "22-foot" coal bed of Upshur County. The detailed structure above given does, indeed, exhibit a bed of this enormous thickness, but it is so split up with slate as to be practically worthless.

Section on the Buckhannon River, Upshur County, West Virginia.—Still further west from this, on the main Buckhannon River, one-fourth of a mile above Grassy Run and 9½ miles from Buckhannon town, in a cut on the West Virginia and Pittsburgh Railroad, the following section is exhibited:

			Feet.
Massive sandstone (Lower Mahoning)			35
Upper Freeport coal	Cannel slate	12′ 0″	17
	Coal	2′ 0″	
	Shale	2′ 0″	
	Coal	1′ 0″	
Gray shale			3
Concealed			10
Massive sandstone in bed of Buckhannon River			5

Here the coal has almost entirely disappeared in the great mass of cannel slate at the top, which, of course, contains a large quantity of bituminous matter.

Section at Lloyd Wamsley's bank, Upshur County, West Virginia.—About 10 miles south from the last locality we come to an area of this coal between the main Buckhannon River and its middle fork, where it has regained a structure more nearly normal, viz:

	Ft.	in.
Cannel slate	0	7
Coal	2	7
Slate, black	0	4
Coal	0	8
Shale, gray	0	8
Coal, soft	1	7

Mr. Bryan's bank, one half mile northwest, exhibits the following:

	Ft.	in.
Cannel slate	0	6
Coal	2	0
Bony coal	0	6
Coal	3	0

Section at Current's farm, Upshur County, West Virginia.—A few miles south of this, near the Randolph County line this coal passes into the air on the land of Mr. Current, where it exhibits the following:

	Ft.	in.	Ft.	in.
Sandstone			25	
Coal	1	0	6	8
Slate, blue	2	2		
Coal	0	2		
Clay	0	10		
Coal	0	6		
Sand rock	1	0		
Coal, visible	1	0		

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Section near Hacker's Valley P. O., Webster County, West Virginia.—Southward from this, through the edge of Randolph, the coal has been eroded by the waters of the Buckhannon, but beyond Helvetia and the Florence Pass we come to an elevated plateau, from which the Buckhannon, Little Kanawha, and Holly (a tributary of the Elk) Rivers all take their rise, and here, in Webster County, 7 miles northeast from Hacker's Valley post-office, we catch an outlier of this coal with the following structure:

	Ft.	in.	
Bony coal	0	6	Ft. in. 5 7
Coal, good	1	3	
Bony coal	1	2	
Coal, good	2	8	

Section on the Little Kanawha River, Lewis County, West Virginia.—About 10 miles northwest from this last locality the same coal exhibits the following structure (according to William S Stevenson) in the hills along the Little Kanawha River, where the left branch of that stream cuts across the panhandle of Lewis County:

	Ft.	in.	
Slaty coal	5	0	Ft. in. 9 0
Coal, hard	2	8	
Slate	0	8	
Coal, softer	1	8	

Section on the Holly River, Webster County, West Virginia.—In the summit of the hills near Anderson's mill, on the left branch of Holly River, Webster County, we find the Upper Freeport coal with the following structure on the land of Mr. Marcum Cougar:

	Ft.	in.	
Coal, hard	3	2	Ft. in. 6 10
Slate, dark	0	4	
Coal, soft	1	4	
Bony coal	0	4	
Coal, soft	1	8	

Section at Powell Mountain, Nicholas County, West Virginia.—To the southwest from this there are no more openings on this coal until we come to Powell Mountain, in Nicholas County, although a "7-foot" bed of coal is frequently "reported" in the hills where the Upper Freeport ought to be found. But in Powell Mountain it has been mined for a long time on the Weston and Gauley Bridge turnpike, where it exhibits the following structure:

	Ft.	in.	
Coal, blossom			Ft. in. 14 3
Shales, gray	10	0	
Coal, splinty	2	0	
Black slate	0	3	
Coal, splinty	2	0	

Here the character of the coal begins to change to the hard, splinty variety which distinguishes the coals of the Kanawha Valley.

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Section on Stroud Creek, Nicholas County, West Virginia.—A few miles east from this, on the waters of Stroud Creek, this bed shows the following section on the land of Dr. D. M. Lewis:

	Ft.	in.	Ft.	in.
Cannel	0	5	12	10
Coal, splint	4	0		
Soft coal	0	4		
Black slate	0	1		
Coal	0	6		
Black, coaly slate	0	6		
Gray slate	3	0		
Coal, soft	1	10		
Clay	1	0		
Coal, soft	0	10		
Slate	0	1		
Coal	0	3		

Sections on Mumble-the-peg Creek, Nicholas County, West Virginia.—On Mumble-the-peg Creek, half way between Powell Mountain and Nicholas Court-House, we find an opening in the Upper Freeport coal on the land of Mr. Herold, where it shows the following structure:

	Ft.	in.	Ft.	in.
Coal	1	6	13	10
Shales	5	0		
Cannel	0	8		
Coal, splinty	2	6		
Slate, black	1	8		
Coal, splinty	2	6		

At another bank, 300 yards west from the last, the following is seen:

	Ft.	in.	Ft.	in.
Coal, blossom			7	4
Shale, gray	2	0		
Bony cannel	0	6		
Coal, splinty	2	1		
Slate, black	0	3		
Coal, splinty	2	6		

At this locality, as well as in Powell Mountain and on Stroud Creek, a very good quality of splint coal is obtained from this bed.

From Nicholas Court-House on southwestward to the Great Kanawha River no openings have been examined along the crop of this coal, but at Cannelton, in Fayette County, we find it a valuable bed of cannel coal with a thickness of 1½ to 4 feet, while 2 to 2½ feet of bituminous coal rests immediately on the latter.

Two miles below Cannelton, at the mouth of Upper Creek, the bed thickens to 11 feet, but the layers of coal are so interstratified and diluted with slate and muddy sediment that the whole is worthless. A few miles farther down the Kanawha, at East Bank and Crown Hill, a portion of this great bed becomes the excellent splint coal, 3 to 4 feet thick, which is mined at those localities, but farther down this river the bed again becomes impure and remains practically worthless from Coalburg on down until it disappears under the river at Charleston.

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West from the Kanawha we have no information about this coal until we reach the Guyandotte River in Cabell and Lincoln Counties, but it is possible that some of the Coal River cannel belongs at this horizon.

Section on the Guyandotte River, Cabell County, West Virginia.—On the Guyandotte River the Upper Freeport coal rises above water level about two miles above the "Falls Dam." It is first opened and mined at the mouth of Stone Coal Run, where it exhibits the following structure:

	Ft.	in.	Ft.	in.
Coal	0	4	3	6
Slate	0	2		
Coal	0	7		
Slate and bony cannel	0	9		
Coal, visible	1	8		

Another opening a short distance up the run gives the following:

	Ft.	in.	Ft.	in.
Massive sandstone			25	0
Cannel slate	1	0	5	3
Slate	0	3		
Coal, good	4	0		

This latter section very probably belongs immediately on top of the first opening, since the interval between the two banks is concealed.

The coal is known in this region as the "big bed." On the Caldwell tract, opposite Camp Branch, this coal exhibits the following section in the bluff overlooking the Guyandotte:

			Ft.	in.
Sandstone, visible			10	0
Coal, Upper Freeport	Coal, slaty	1′ 0″	10	5
	Coal	1′ 6″		
	Slate	0′ 1″		
	Coal	2′ 0″		
	Slate	0′ 2″		
	Coal	0′ 9″		
	Shale	0′ 9″		
	Coal	0′ 8″		
	Slate	0′ 6″		
	Coal	3′ 0″		

As will be perceived, the coal contains much slaty material and the layers of coal themselves are inclined to be bony and impure, approaching the type which this bed exhibits in the vicinity of the Kanawha Mining Company's plant on the Big Kanawha River.

Sections on Cove Creek, Wayne County, West Virginia.—As we pass from the Guyandotte in Lincoln County westward across the divide to the waters of Twelve Pole, a great change takes place in the Upper Freeport bed, and on Cove Creek we find it split into two portions with 30 feet of rock between, and the lower bench a fine quality of cannel coal 3 to 4 feet thick at some openings.

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At another locality the following is seen:

		Ft.	in.	Ft.	in.
Coal blossom		2	0	36	10
Shales and sandstone		30	0		
Shale	0′ 6″				
Coal, splint	1′ 8″				
Cannel, good	1′ 4″	4	10		
Coal, bony	1′ 4″				

On the opposite side of Cove Creek we see:

	Ft.	in.	Ft.	in.
Massive sandstone			5	4
Coal	0	6		
Slate	0	4		
Coal	1	6		
Cannel	3	0		

From this point a belt of cannel coal at the horizon of this bed extends in a general westerly direction nearly across Wayne County, being found on all of the main branches of Twelve Pole. It is possibly identical with the celebrated Moses Fork cannel and other cannel deposits in Kentucky. This belt of cannel varies much in width, but it is often 2 or 3 miles across, and while the bed is not entirely persistent, it is seldom less than 20 inches thick. It is quite pure and will compare favorably with the celebrated Kanawha cannel, which comes at the same geological horizon.

On the left branch of Twelve Pole, one-half mile above the mouth of Brush Creek, this cannel coal shows as follows:

	Ft.	in.	Ft.
Massive sandstone			4
Coal, bituminous	0	10	
Rock, dark	0	8	
Cannel	2	6	

On Little Laurel, a branch of Hezekiah Creek (tributary of the left fork of Twelve Pole), the cannel exhibits the following:

	Ft.	in.	Ft.	in.
Sandstone			5	5
Coal, bituminous	1	0		
Bone coal	0	8		
Cannel	3	1		
Bone coal	1	8		

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On Saw Pit branch of Cove Creek the following section was measured:

	Ft.	in.	Feet.
Coal, blossom	2	0	27
Sandstone	25	0	
Coal	0	6	8
Slate, gray	0	1	
Coal, bituminous	1	3	
Cannel	1	7	
Coal, splint	1	0	
Slate and slaty coal	0	5	
Coal	0	5	
Slate	0	2	
Coal, splint	0	8	
Slate, blue	0	5	
Coal, splint	1	6	

In Sugar Camp Hollow, a short distance above Jesse Queen's, the Upper Freeport coal exhibits the following structure:

	Ft.	in.	Ft.	in.	Ft.	in.
Sandstone, massive						
Coal	2	4				
Slate	0	2				
Coal, splint	1	2				
Slate, gray	0	4				
Coal	0	2				
Slate, gray	0	4				
Coal, splint	0	8	8	11	25	5
Slate, gray	0	4				
Coal	1	6				
Slate, dark	0	9				
Coal	0	7				
Slate	0	6				
Coal	0	1				
Shaly sandstone			15			
Coal			1	6		

On Trough Creek, near James Rainey's, this coal exhibits the following:

	Ft.	in.	Ft.	in.	Ft.	in.
Massive sandstone						
Cannel slate	0	5	3	3	24	7
Coal, splinty	1	9				
Slate	0	1				
Coal, splint	1	0				
Flaggy sandstone and shale			15	0		
Cannel slate	0	8	6	4		
Coal	2	1				
Slate	0	2				
Coal	0	10				
Shale, gray	0	6				
Coal	2	1				

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At Greene Porter's, on the right bank of Twelve Pole, the Upper Freeport bed shows the following:

	Ft.	in.	Ft.	in.
Coal	1	0	7	4
Clay	0	5		
Shale and coal	0	9		
Coal	1	10		
Bony coal and slate	1	0		
Coal	2	4		

From this point on west to the Kentucky line on the Tug River nothing is known of the Upper Freeport coal, and at Warfield it seems to be absent from the section, but this may possibly be due to the fact that its horizon there overtops the summit of the hills.

In western Pennsylvania there are large areas, especially in Beaver County, where this coal is either absent or else too thin to mine; so it enters Ohio not as a persistent bed, but occurring in patches, and this characteristic seems to remain with it there, from the Pennsylvania line entirely across the State to the Kentucky border at Ironton.

Even along the Ohio River from the Pennsylvania line down to where this bed dips below the same, it is generally absent, and Prof. Orton thinks it is still absent in the Steubenville shafts, the coal mined there being the Lower Freeport bed, instead of the Upper Freeport as was formerly supposed.

In eastern Ohio it is known as bed No. 6 in the Ohio scheme of numbers, but in other portions of the State, as Prof. Orton has shown, it was often called No. 7. The following list of Ohio names for this bed will indicate regions in that State where the bed becomes prominent: "Big Vein" of Salinesville, "Dell Roy," "Cambridge," "Alexander," "Bayley's Run," "Norris," "Happy Hollow," "Waterloo."

Section near Kenova, West Virginia.—After passing beneath the Ohio River above Steubenville, this bed never emerges from the same until within 2 miles of the Kentucky line, and if the Steubenville shaft coal be the Lower Freeport, then the Upper one is absent over a wide region along the Ohio River, for it appears to be absent in several borings, notably at Parkersburg and Pomeroy. It is reported from a boring at Huntington, however, as 10 feet thick, though where it comes up to the level of the Chesapeake and Ohio Railroad at the east end of the Big Sandy bridge, 10 miles below Huntington, the bed is worthless, as shown by the following structure there:

	Ft.	Ft.
Coal	1	5
Shale	3	
Coal, slaty	1	

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Section in Ritchie County, West Virginia.—Where this bed is brought to the surface on the Volcano anticlinal in Ritchie County, West Virginia, it has the following structure, according to Stevenson:

	Ft.	in.	Ft.	in.
Coal	2	6	6	8
Sandstone, gray	3	6		
Coal	0	8		

THE UPPER FREEPORT LIMESTONE.

Below the coal just described, at an interval which varies from 0 to 40 feet, there comes a limestone which was named from the same locality as the coal. It is quite generally distributed in Pennsylvania, northern West Virginia and Ohio, but in the southwestern part of West Virginia it appears to be absent, since it has never been reported from the region along the Big Kanawha and its tributaries, nor from the region between that and the Big Sandy.

The limestone is usually of a light gray color on fresh fracture, but some of the layers are always buffish when weathered, owing to included iron. Frequently the rock presents a brecciated aspect, as if made from the broken fragments of an older limestone.

Fossils are rare in this bed except a minute univalve which looks as if it might be of fresh water origin. Some layers of this stratum generally contain a considerable amount of carbonate of magnesia, and occasionally enough to constitute it a good rock for the manufacture of hydraulic cement.

The thickness varies from 1 foot up to 30 feet as a maximum, though the average might be placed at 5 to 8. It makes an excellent lime for fertilizing purposes, and is much sought after to enrich the barren soil lands above, though it is occasionally mined for use in blast furnaces, as on the Alleghany River between Freeport and Kittanning, where it is unusually thick.

In Ohio this bed has been given several names, as "Shawnee," "White," "Buchtel," etc. There, also, as in Pennsylvania and West Virginia, it occasionally becomes iron-bearing and some or all of its layers develop into iron ore, which is known in Ohio as the "Buchtel" ore, and in Pennsylvania as the "Summit" ore.

THE BOLIVAR FIRE CLAY.

When the Upper Freeport limestone is absent, or but slightly represented, there occasionally comes into the section at its horizon a bed of excellent fire clay, which from having long been mined near Bolivar, Westmoreland County, Pennsylvania, is generally known as the Bolivar clay. As there developed it shows a fine quality of non-plastic clay which is used in the manufacture of fire brick and gas retorts. It also occurs in several other regions of Westmoreland County, as well as in Fayette and other Pennsylvania counties.

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This clay has been reported as valuable at only two or three points in Ohio, viz, in Jefferson and Muskingum Counties, while in West Virginia it is known to be valuable in only one region, viz, on Deckers Creek, in Preston and Monongalia Counties.

THE UPPER FREEPORT SANDSTONE.

As a rule the main portion of the interval between the Upper and Lower Freeport coals is occupied by sandy shales or thin flaggy layers of sandstone, separated by shales, but occasionally a bed of massive sandstone makes its appearance at this horizon and it has received the name of Upper Freeport Sandstone. It is quite prominent in some portions of Pennsylvania, but appears to be generally absent in Ohio. It is also conspicuous along the Great Kanawha and in all the region of West Virginia, southwest from there, sometimes attaining a thickness of 75 feet, while in Pennsylvania it is seldom more than 30 feet.

When this sandstone is not present as a massive rock there occasionally occurs a thin bed of coal in the interval between the Upper and Lower Freeport coals, and I have termed it

THE MIDDLE FREEPORT COAL.

This bed is shown in Section 66 at the typical Freeport locality, and as already stated in connection therewith, its presence in other sections may have led to some confusion in identifications. It is not a regular member of the series, however, and is probably never much thicker than at Freeport, viz, 2 feet.

The interval between the Upper and Lower Freeport coals varies greatly in thickness, running up sometimes to 80 and again thinning away to 20-odd feet, as shown in Section 65.

THE LOWER FREEPORT COAL.

This bed is quite as variable, or even more so than the Upper Freeport above. The rule is that whenever one of these beds has a fair development the other is poor or worthless, but in addition to this uncertainty, they are both frequently thin, or practically absent from the section at the same time, so that no one should look upon any of these coal beds as being continuously valuable over wide areas.

As shown in Section 66 at the type locality of this bed, it is even more complex in its structure than the Upper Freeport above, being split into two well defined layers separated by a stratum of clay and limestone. It is quite probable that this dividing layer may at times thicken up greatly as all other rocks do, and separate the two layers of coal by an interval of several feet, thus making two apparently distinct coal beds, but which should really be classed as members of one.

If Messrs. Chance and Platt are correct in the identifications of the Lower Freeport coal in Jefferson and Clearfield, there are large areas in both of these counties where this coal is quite valuable, since it is 4

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to 7 feet thick and of excellent quality, though it is always separated into two or three benches by partings of slate.

The upper portion of the Lower Freeport bed often has a tendency to become cannelly, as at Freeport, and some highly bituminous shale is frequently present at this horizon, even when the coal is absent.

Another very fine development of the Lower Freeport coal is in the vicinity of Fairmont, Clarion County, Pennsylvania, where according to Chance it is 5 to 7 feet thick without any partings, and furnishes an excellent quality of gas coal, as it does in the Reynoldsville region of Jefferson County.

In Ohio the reputation of the coal as a patchy deposit is fully sustained, since Prof. Orton says of it (Vol. V, p. 166, Ohio Geological Survey), "this is a seam the horizon of which can be followed throughout the entire field, but which becomes workable at comparatively few points."

In eastern Ohio it is called No. 5, but in Stark County and southwestward it is known as No. 6a, while the synonyms, "Whan" "Steubenville Shaft," "Roger," "Hamden Furnace," and "Hatcher" indicate localities where the bed becomes important.

If the "Steubenville Shaft" bed really represents this coal instead of the Upper Freeport, then there is quite a large field of it along the Ohio River, for it is found of good thickness in every boring as far south as Moundsville, West Virginia, where it underlies the Ohio by more than 600 feet.

Section near Philippi, Barbour County, West Virginia.—In Preston, Monongalia, Mineral, and Tucker Counties, West Virginia, this bed is quite thin and often absent entirely, so it is not mined till we go south into Barbour County, where it thickens up and in the vicinity of Philippi exhibits the following structure:

	Ft.	in.	Ft.	in.
Coal	1	10	5	10
Slate	0	8		
Coal	0	6		
Slate and coal	0	10		
Coal	2	0		

Nothing is known of the Lower Freeport from Philippi on southwestward along the eastern margin of the Appalachian field until the Great Kanawha River is reached, except in the Roaring Creek field, where it is only 2 feet thick and 25 feet below the upper bed.

But from the fact that this coal becomes one of the principal beds in the Kanawha region, and from there on southwestward into Kentucky, it is inferred that it is also a valuable bed at some points between Philippi and the Big Kanawha.

On this latter stream the Lower Freeport appears to be the parent of two valuable beds known respectively as the Coalburg and Winnifrede veins. The former certainly belongs to this horizon, and the latter

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probably does, though formerly I was inclined to refer it to the horizon of the Upper Kittanning. The Lower Coal Measures thicken up so greatly in that region, however, and the intervals separating the Coalburg and Winifrede beds from the top of the series and from each other vary so much that it seems more probable they are both members of the complex Lower Freeport coal. The Coalburg and Winifrede beds are themselves complex, being always separated into two or three benches by layers of very hard slate or bony coal locally known as "nigger head." They usually furnish the variety of coal known as "splint," and the Kanawha "splint" is highly prized as a general domestic fuel. These two beds are quite irregular in their thickness and one or both are often too thin to mine, but they appear to be much more regular and persistent southwest from the Kanawha than the Upper Freeport, since they furnish valuable coal clear across to the Big Sandy River, the celebrated Peach Orchard coal of Kentucky coming at the horizon of either the Coalburg or Winifrede bed, or both combined. This latter view is the more probable, since at the tunnel near the New Peach Orchard mine the coal is seen splitting up till it is scattered through more than 40 feet of rock material.

Section of bed at Coalburg, Kanawha County, West Virginia.—The following section shows the variations in the structure of the Coalburg bed at its typical locality:

Splint coal	6 in. to 10 ft.
"Nigger head"	4 in. to 8 in.
Splint coal	2½ ft. to 3½ ft.
Shale	1 ft. to 8 ft.
Soft coal	1 ft. to 1½ ft.

Section at Winifrede, Kanawha County, West Virginia.—The structure of the Winifrede coal at Winifrede is as follows:

	Ft.	in.	Ft.	in.
Gray splint	0	5	4	10
Soft coal	0	5		
Gray splint	0	3		
Soft coal	0	3		
Gray splint	1	2		
Soft coal	1	3		
Slate	0	5		
Soft coal	1	8		

I do not know of any locality in the Kanawha Valley where both the Winifrede and Coalburg beds are mined one above the other in the same hill, for when one is good the other happens to be worthless, and this is so constantly true that, were it not for the fact that the Coalburg bed is only 100 feet below the Kanawha black flint while the Winifrede seam is 175 to 200 feet below the same datum line, I would be strongly inclined to believe that they were one and the same coal.

Section at mouth of Blaine Creek, Lawrence County, Kentucky.—In descending the Big Sandy River the Lower Freeport sinks below water

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level at the mouth of Blaine Creek, 6 miles below Louisa, where it exhibits the following structure:

	Ft.	in.	Ft.	in.
Massive sandstone				
Coal	0	10	7	10
Fire clay	5	0		
Sandy shale	2	0		
Coal	0	10	5	7
Shale with iron ore	1	0		
Coal, slaty	1	0		
Shale, blue	1	3		
Coal	1	6		

THE LOWER FREEPORT LIMESTONE.

The conditions preceding the spread of a great coal marsh seem to have been eminently fitted for the production of limestone deposits, especially in the Pennsylvania and Ohio regions, for, with few exceptions, a limestone is found close under every coal bed, and this is true of the Lower Freeport horizon. This limestone very much resembles the one under the Upper Freeport coal, except that it is usually thinner and more earthy. It also contains the same univalve fossil, and no others, so far as the writer is aware, thus showing that it too is a fresh-water deposit. It contains a considerable quantity of carbonate of magnesia and occasionally, as at the locality of Section 103, furnishes material for the manufacture of hydraulic cement.

Considerable iron ore is also found at this horizon, and the limestone is generally of a buffish cast from the disseminated iron. From this fact it and the Upper Freeport limestone above are generally called the "buff" limestones in southern Ohio.

In West Virginia this limestone has not been recognized anywhere in the northern part of the State, and it is certainly absent entirely along the Great Kanawha. An impure limestone is sometimes found in connection with the Peach Orchard coal of Kentucky, which is possibly identical with the Lower Freeport.

THE LOWER FREEPORT SANDSTONE.

The next lower stratum that has a general distribution over the Appalachian field is known as the Lower Freeport sandstone. Section 66 shows the thickness and structure of this sandstone at its typical locality, and there it is seen to be double, with a coal embedded in its lower portion, the whole being 62 feet thick. That the 15 feet of sandstone under the coal at Freeport belongs properly with the main sandstone above is known from the fact that at one locality the coal is seen disappearing entirely and then the two beds of sandstone unite into one solid mass.

This rock is always of a grayish white color, generally quite hard often containing pebbles as well as much feldspar, which decomposing permits the rock to disintegrate readily and weather into fantastic

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shapes. It is more persistent as a massive rock than the Mahoning even, but unlike the latter it is seldom used for building purposes. This is owing to its hardness, coupled with the fact that it will not stand the weather well, and also it is often so gnarly and twisted in its bedding that it will not split evenly.

This sandstone is never less than 30 feet thick in the Pennsylvania region, and it frequently rises to 75 and even 100 feet in some localities, making a bold cliff or bluff wherever its outcrop is above drainage, and thus becoming a conspicuous feature in the topography of the Lower Coal Measures.

Throughout a large portion of Beaver County, Pennsylvania, this sandstone is 75 to 80 feet thick, and near its center is a very hard calcareo-siliceous layer 2 or 3 feet thick, which may possibly represent the Johnstown Cement limestone in other portions of the State.

The sandstone maintains about the same thickness throughout eastern Ohio as in Beaver County, and continues on around to southern Ohio with a thickness of 30 to 50 feet.

It enters West Virginia from Pennsylvania as a very massive bed, 50 to 75 feet thick in Monongalia and Preston Counties, while in Tucker, Taylor, Barbour, and Randolph, it is still thicker and more pebbly even than the Pottsville conglomerate. Southwestward through Randolph, Webster, Braxton, and Clay, this sandstone keeps on increasing in thickness, and when the Big Kanawha is reached it has swelled out in a wonderful manner, becoming 250 to 300 feet thick, and remaining the same across to the Big Sandy, often crowning the hills and ridges with cliffs weathered into turreted and chimney-shaped forms. When attaining this immense thickness it often consists of three or four sandstones, with shales and two or three coal beds interstratified.

This rock has produced a small quantity of oil at Fairview, Marion County, West Virginia, and is generally known as the "gas sand," in the drillers' parlance, since it often produces considerable quantities of natural gas.

THE UPPER KITTANNING COAL.

Throughout several counties of Pennsylvania a third bed of good coal occurs at 80 to 120 feet below the top of the series, and to this Messrs. Chance, Platt, and other Pennsylvania geologists, have given the name Upper Kittanning, though the bed in question is not workable at Kittanning or anywhere near that town, as may be seen from Sections 60–66 along the Alleghany River, since it is thin and unimportant in that region. The Messrs. Platt at one time identified this coal with the Lower Freeport bed in Cambria, Clearfield, and Jefferson Counties, calling the coal which is now termed Lower Freeport there the Middle Freeport, and it is barely possible that this first arrangement of the stratigraphical order was the correct one in many regions, since, as already shown (see 66), there is a Middle Freeport coal even

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at Freeport, and in addition the Lower Freeport bed is itself so complex that either half of it might at any time separate from the other and both become independent beds.

But however the questions suggested may turn out, the fact remains that at many localities in Pennsylvania, at least, there are three distinct coal beds between the Ferriferous limestone and the Lower Freeport coal, as shown in Sections 64, 65, and 66.

Westward in Ohio, however, the Upper Kittanning coal appears to be either wanting entirely in most cases or else coalesced with the Middle Kittanning bed, since Prof. Orton finds no place for it as a regular member of the Ohio series, but puts it down as a synonym for the Lower Freeport seam. (See Vol. V, p. 126, Ohio Survey.)

In West Virginia the Upper Kittanning bed first appears in the sections along the Tygart's Valley River (96 and 97), where it is 2 to 3½ feet thick, and a rather fair coal; but it appears to be absent entirely in the Newburg shaft, Preston County, unless it is combined with the Middle Kittanning there, while in the North Potomac basin near Davis it is represented by a mere streak. In the Kanawha field two or three thin beds come at this horizon, and one of them is frequently cannel, and the same horizon can be recognized on the Guyandotte River, in Wyoming County (Section 117).

Chance says that it is the main cannel horizon in Pennsylvania, the New Bethlehem, North Washington, and Murrinsville cannel deposits coming at this horizon. If the Darlington cannel, of Beaver County, comes at this same horizon, then the interval separating the Upper and Middle Kittanning beds has there thinned entirely away, and thus brought the two into direct contact. This might well be, since the Darlington cannel rests directly on 2 feet of bituminous coal, below which, through a shale interval of 30 feet, comes the undoubted Lower Kittanning coal, underlaid by its great bed of fire clay. This would account for the absence of the coal in Ohio, if it really does unite with the Middle Kittanning before crossing the Pennsylvania-Ohio line.

This bed appears to attain its greatest importance in Pennsylvania, along the eastern border of the coal field through the counties of Jefferson, Clearfield, Cambria, and Somerset, where it has been fully described by Messrs. Platt and Chance. The general sections already given show the horizon and structure of this bed at numerous points, so that no further description of it is necessary.

THE JOHNSTOWN (CEMENT) LIMESTONE.

Lying only 2 to 5 feet below the coal just described, there occurs, over a wide region in Pennsylvania, a bed of magnesian limestone, which Mr. Franklin Platt named the Johnstown Cement, from its occurrence at the city of Johnstown, Cambria County. It is almost an exact counterpart of the Lower Freeport limestone of the counties farther west in physical aspect, chemical composition, fossils, and everything else, and

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this is one of the facts which, taken in connection with the entire absence of this limestone in the western tier of counties and in Ohio, has sometimes led to the suspicion that possibly the Johnstown Cement and the Lower Freeport limestone of Butler and Beaver Counties are identical. Still there are other facts of stratigraphy which appear to forbid such an hypothesis, and hence, until it can be shown otherwise by more positive demonstration, we must accept the stratigraphical horizon given the Johnstown Cement first by Messrs. Platt, whose labors moved it up from the horizon of the Ferriferous limestone, to which the First Geological Survey of Pennsylvania had erroneously assigned it. The stratum ranges in thickness from 1 to 8 feet, and when it is 5 feet or more some of the layers often make good lime for agricultural or other purposes; but when the bed is only 1 to 3 feet thick it is usually too impure to slake well. This stratum has not been recognized at any point within West Virginia with which the writer is familiar, and it thus appears to be generally absent from the series in that State.

THE MIDDLE KITTANNING COAL.

Whatever uncertainty may exist concerning the exact horizon of the coal which has just been described under the name of Upper Kittanning, there is none with reference to the next lower bed, for it is such a constant member of the series that its relations to the other rocks are seen in nearly every section. This bed was formerly called the Upper Kittanning, until Messrs. Platt and Chance discovered that the coal last described was a member of the Kittanning group, and then the coal in question was lowered to the name of Middle Kittanning.

In the vicinity of Kittanning (Section 63), and along the Allegheny River below (Sections 64, 65, and 66), this bed is thin and unimportant, but west from this it thickens up and is the most important seam in Butler, Lawrence, and Beaver Counties, the coal being quite pure and highly esteemed for gas, steam, and domestic purposes, though it seldom exceeds 4 feet in thickness, and is often much less. This is the famous "Clinton," "Rock Point," and "Hog Hollow" coal along the Beaver River. It is always divided by one or more thin slate partings, one of which is usually near the bottom.

Eastward from Butler County, through Armstrong, Clarion, Jefferson, and Clearfield, this bed, according to Platt and Chance, declines much in thickness and value, so that it is seldom mined, except occasionally for domestic purposes.

Still farther eastward, however, in the Broad Top coal field of Huntingdon and Bedford Counties, it thickens up and is apparently represented by the "Barnet" coal of that region.

Southward from Pennsylvania, in Maryland and northern West Virginia, this coal is sometimes thick enough to mine, though seldom exceeding 2½ to 3 feet. At the southern end of the North Potomac

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coal basin it practically unites with the Lower Kittanning below, and is mined with the latter where that bed is opened near Thomas; but at the Davis mine, further south, the parting slates have thickened up to 20 feet and separated it from the Lower Kittanning again.

Section at Newburg, Preston County, West Virginia.—In the deep shaft at Newburg, Preston County, West Virginia, this coal has the following structure and relations to other beds:

		Ft.	in.	Ft.	in.
1. Lower Freeport sandstone					
2. Coal, Middle Kittanning	Coal	1	0	7	3
	Slate	0	3		
	Coal, slaty	2	0		
	Clay	2	0		
	Coal, good	2	0		
3. Fire clay and shales				15	0
4. Coal, Lower Kittanning, with several partings				9	5

Here it is possible that both the Upper and Middle Kittanning beds are represented in No. 2, and they are only 15 feet above the Lower Kittanning coal.

In the Great Kanawha field, this bed, although only 3 to 4 feet thick, is very pure and valuable, being known there under the names of "Cedar Grove," "Trimble," "Arno," and others.

In the Wyoming County section (117) two beds are often found at this horizon, separated by 20 feet of shales, but the lower one appears to be the main coal. The same thing is seen in the Peach Orchard section (119), where the lower one is a "splint" coal, thin, but of excellent quality.

In Ohio this coal becomes the most important bed of all the coals in that State, according to Prof. Orton, since it is almost constantly workable from where it enters Columbiana County on the east to where it leaves the State near Ironton at the southwest. The numerous names it has received in Ohio will serve to illustrate its importance in the mining industry there, of which the following is a partial list: "No. 4, in Ohio and Yellow Creek Valleys at the east; "No. 6," in Stark County and southwestward; "Hammondsville Strip Vein," "Onasburg," "Pike Run," "Dennison," "Coshocton," "Upper Zanesville," "Upper New Lexington," "Nelsonville," "Straitsville," "Great Vein" of the Hocking Valley, "Carbondale," "Mineral City," "Upper Zaleski," "Washington Furnace," "Sheridan," etc.

The tracing of this bed through Ohio, and its identification at many points where it had formerly been confused with other beds, is due largely to the labors of Prof. Orton, the present efficient director of the Ohio Geological Survey. The structure of the coal where it attains a considerable thickness, as in the Hocking Valley, is always quite complex, there being several parting slates, as may be seen from Sections 105 and 106.

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Section in Hocking Valley, Ohio.—The following, from Vol. V, Ohio Geology, will serve to illustrate the general structure of this bed when at its maximum development:

	Ft.	in.	Ft.	in.
Top coal	2	7	11	8
Soft coal, rejected	0	4		
Coal	4	2		
Bone coal, rejected	0	6		
Second slate	0	2		
Coal	1	6		
First slate	0	1		
Coal	2	4		

Section at New Straitsville, Perry County.—The following is the structure at New Straitsville, p. 954, loc. cit.:

	Ft.	in.	Ft.
Coal	1	2	10
Bone coal	0	2	
Coal	4	0	
Soft coal	0	4	
Slate	0	3	
Coal	2	1	
Slate	0	1	
Coal	1	11	

According to Orton this bed changes in character from a good coking coal in eastern Ohio to an open-burning one from New Lexington southwestward. The reader will find the coal fully described in Vol. V, Ohio Geology.

The interval separating the Middle Kittanning coal from the Lower Kittanning bed varies greatly both in thickness and composition in the different regions of the Appalachian field. In western Pennsylvania and eastern Ohio the interval is usually only 20 to 30 feet and generally occupied with dark slates or shales holding iron nodules, and it seldom surpasses 40 feet anywhere in Pennsylvania, while in northern West Virginia it locally thins away to an insignificant parting, but to the southwestward in the Great Kanawha region, and from there across to the Big Sandy, it often swells up to 100 feet and occasionally attains a thickness of 165 feet (Section 115), with some massive sandstone at several horizons. In southwestern Ohio a massive sandstone 30 to 40 feet thick often occupies the interval to the exclusion of shales.

In the Great Kanawha region a siliceous limestone makes its appearance in this interval and seems to have quite a wide distribution in that region and southwestward to the Big Sandy. It is well exposed near the mouth of Campbell's Creek, and I have designated it the Campbell's Creek limestone from that locality. This stratum seems to be present even in northern West Virginia, since in Sections 95 and 96, at Moatsville and Valley Falls, respectively, a bed of siliceous limestone occurs 20 feet above the Lower Kittanning coal.

Along the Tug Fork of Big Sandy there are siliceous limestones at

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several horizons above the Campbell's Creek bed, as shown in Section 119, there being two and sometimes three within the horizon of the Lower Freeport sandstone, so that these must not be confounded with the one in question.

The bottom layers of this shale interval immediately above the Lower Kittanning coal are nearly always filled with fossil plants. They occur in great variety and abundance wherever the rock material in the roof of the underlying coal is a shale, and this is the horizon par excellence for the collector of plants from the Lower Coal Measures.

These beds have been thoroughly explored at only one locality in the Appalachian field, viz, Cannelton, Beaver County, Pennsylvania, where Mr. I. F. Mansfield has collected systematically for Prof. Lesquereux during several years, the results of which are recorded in Report P, Vols. I and II, Second Geological Survey of Pennsylvania. The list includes a large number of species, several of which are peculiar to that locality.

THE LOWER KITTANNING COAL.

The next lower bed of this series, though formerly named simply the Kittanning coal by Rogers, is now called the Lower Kittanning. Although seldom attaining any unusual thickness, it is probably the most persistent bed in the entire Appalachian field, and has a workable thickness over a larger area than any other. In Pennsylvania it furnishes from 3 to 4 feet of valuable fuel over large areas in every county where its outcrop is due. Of course, like all other coals, it thins down locally and becomes worthless over considerable areas, but the barren patches on the horizon of the Lower Kittanning bed are fewer and smaller than those at the horizon of any other coal in the entire Lower Coal Measures. If the Middle Kittanning is the more important coal in Ohio, the Lower surpasses it in Pennsylvania and West Virginia, so that the difference in favor of the former in Ohio is much more than offset in the latter two States. This coal is also a composite seam, and when it acquires considerable thickness is often split into several divisions by separating slates. In the Pennsylvania field these slates are usually mere knife edges, and add but little to the total thickness of the bed, except in the eastern portion of the field, where in Clearfield, Bedford, and Huntingdon it often has a layer of impure fire clay or gray shale separating the bottom member from the middle one.

The "Fulton vein" of the Broad Top field appears to be identical with this coal, though the writer was formerly inclined to regard it as identical with the Clarion (see T^3, Second Geological Survey of Pennsylvania), and bed "A" of the Tipton Run series is probably the same.

The "Bloss vein" of Tioga County seems to be referable to this same horizon both with reference to structure and its position in the column of rocks (Sections 50 and 51).

In the Georges Creek field of Maryland this is often known as the "6-foot" bed, and its structure there is given in Section 92. From Elk

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Garden southward along the North Potomac to where this bed passes under drainage level, near Gorman, it is so badly split up with slate as to be rather valueless, but where it emerges to daylight again on the other side of the Cheat-Potomac divide, near Thomas, it has become a splendid vein nearly 11 feet thick, as shown in Section 94, from which 6 feet of excellent coal is mined without taking out the bottom member. As already stated, the bed attains its great thickness in this region by the thinning away of the shales which usually separate the Middle and Lower Kittanning beds, thus permitting the two practically to unite into one. The coal from it here is prized for smithing purposes quite as highly as the celebrated Blossburg bed, with which it appears to be identical. It has also been successfully coked in this Tucker County field, since it is nearly always a good coking coal everywhere.

Section at Newburg, Preston County, West Virginia.—In the deep shaft at Newburg, Preston County, West Virginia, the Lower Kittanning has the following structure:

	Ft.	in.	Ft.	in.
Coal	0	10	9	5
Shale, gray	0	10		
Coal	0	6		
Bony coal	0	3		
Coal	4	6		
Black slate	0	6		
Coal	2	0		

Sections 95 and 96 show the structure of this bed where it is brought to the surface by the Chestnut Ridge anticlinal, on the Tygart's Valley River, below Grafton, West Virginia, and, as will be seen, it is there about 5 feet thick.

On the Great Kanawha River, above Charleston, this is one of the principal coal beds, and has long been known there as the Campbell's Creek vein. At this locality on Campbell's Creek the coal is 4 to 6 feet thick with only two parting slates, but in passing southward up the Kanawha new partings come in and the old ones thicken up until the bed, with its included rock partings, swells out to a thickness of nearly 50 feet, and two of the members are mined independently, the upper one being known as the Peerless bed and the lower one as the Blacksburg. The upper member never exceeds 3 feet, and is usually about 20 feet above the Blacksburg member, which is often 4 to 5 feet thick and is the "Coal Valley gas vein." On the Mount Carbon property, 25 miles south from Campbell's Creek, the 20 feet of shales which usually separate the Peerless and Blacksburg members of the Lower Kittanning coal thin away to a few inches locally, and both are taken out of the same drift. This is also the condition of affairs at the famous Austead mines of the Hawk's Nest Coal Company on top of Gauley Mountain. At the head of Cabin Creek, a tributary from the south bank of the Big Kanawha, the Peerless and upper half of the Blacksburg member come completely together, forming a bed of excellent gas coal 5½ feet thick.

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In Wyoming County, West Virginia, this coal, which is locally called the "Cook vein," has a good development, the whole seam with its parting slates being about 25 feet thick, as may be seen from Section 117, but the main portion of the bed is about 7 to 8 feet thick, separated into three layers by slate partings of 4 to 6 inches thick.

This coal rises above the level of the Tug Fork of Big Sandy about 3 miles below Warfield and 30 above Louisa. It has been mined to some extent for local use at Warfield, and is known in that region as the "Warfield coal." Its structure there is given by Section 119. Above Warfield it dips down under the stream and does not come up again for about 10 miles, or some distance above the mouth of Pigeon Creek, but from there on up Tug River it is constantly accessible for about 40 miles, until the southward rise of the rocks throws the coal above the tops of the hills near the mouth of Ben Creek, 95 miles above the mouth of Tug. Along this line the coal is seldom less than 3 feet thick and frequently 4 to 5 feet, with only one slate parting 3 to 5 inches thick. At the mouth of Lick Creek and 60 miles from Louisa this coal is 100 feet above the river, and reported 6 to 7 feet thick, with only one thin slate near the center.

In Ohio the Lower Kittanning coal is almost as persistent as in Pennsylvania, rarely being absent entirely from the section, and generally having a thickness of 3 feet, with a maximum of 5.

In the deep oil-borings across southwest Pennsylvania and northern West Virginia this coal is quite persistent, being frequently reported at a depth of 1,500 to 1,800 feet beneath the surface.

The following list of names has been given it in Ohio: Coal No. 3 in Ohio Valley and along Yellow Creek, No. 4 at Leetonia, No. 5 in Stark County and southwestward; also "Creek vein," "Potter's vein," "Leetonia," "Mineral Point," "Lower New Lexington," "Newcastle," etc. This coal is often neglected in Ohio even when it has a thickness of 2½ to 3 feet, because of the great development of the Middle Kittanning coal only a few feet above. Both of these beds have now, through the labors of Newberry, Orton, Roy, and others, been traced from the Pennsylvania line clear across Ohio to where they pass into Kentucky at Ironton, and have been so well described by Orton in Vol. V, Ohio Geology, that it is unnecessary for the writer to dwell on them longer.

THE KITTANNING FIRE CLAY.

Lying directly under the last described coal there comes in many regions a great bed of splendid fire clay which often overshadows the coal in value, since many millions of dollars are invested in manufacturing the several lines of articles which can be made from this clay. The bed has been named from Kittanning, where it is mined, and here as well as at many localities in Ohio the clay does not all immediately underlie the coal, but some of it is found a few feet lower and nearly on top of the Ferriferous limestone.

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Eastward from the Alleghany River this clay does not appear to be very important, but westward from that point it is generally present, and attains its maximum development along the Beaver, and westward from there down the Ohio; the famous potteries at New Brighton, Rochester, East Liverpool, New Cumberland, and other points in these valleys all deriving their clay from this horizon.

In the Beaver County region the thickness is generally about 8 to 10 feet, but occasionally runs up to 15 and down to 5. It often consists of two portions, an upper "soft" clay and a lower "hard" clay, the latter being used in the manufacture of fire brick, etc. In western Pennsylvania and eastern Ohio this clay bed is often a very valuable element in settling questions of stratigraphy which would otherwise be extremely difficult of solution; in fact it is valuable for this purpose clear across the Ohio coal field, since, according to Orton, although not entirely persistent, yet it furnishes valuable clay mines in every county of its outcrop from the Pennsylvania line across to the Kentucky border.

In West Virginia (except along the Upper Ohio River) the deposit is seldom of value, being too siliceous, and it has been developed in only one region, viz, near the locality of Section 97, at Nuzum's, on the Tygart's Valley River. Here along the crown of the Chestnut Ridge anticlinal the coal above locally disappears, and then a valuable bed of hard clay replaces it, but when the coal comes in again the clay disappears, just as it often does in Ohio, when the hard flinty clay is present. The Glade Fire Brick Works at Nuzums manufacture a good fire brick from this bed.

THE KITTANNING SANDSTONE.

The interval between the Lower Kittanning coal and the Ferriferous limestone varies greatly in thickness, sometimes only the clay bed just described intervening, and again the interval thickens up to 50 to 75 feet or even more. Whenever the interval attains anything like these last figures we generally find a massive sandstone between the coal and the limestone, and to this has been given the name Kittanning. It sometimes, as on Buffalo Creek, Butler County, Pennsylvania, develops into a great cliff rock of massive and even pebbly sandstone, cutting out the underlying limestone (Ferriferous). It often furnishes good quarry stone, and a rock occupying this horizon in the series has been quarried and used in building the Government lock and dam near Coal Valley, on the Great Kanawha River. In this region the interval between the Lower Kittanning coal and the Ferriferous limestone thickens up to 150 feet, and a local bed of coal, the Brownstown, comes into the series about half way in the interval. In Wyoming County and westward from there the Kittanning sandstone thickens to 100 feet, as seen in Section 117.

THE BUHRSTONE IRON ORE.

Resting immediately on top of the Ferriferous limestone there occurs over a very wide area a deposit of iron ore. In Pennsylvania it is often

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underlaid with cherty material, and hence long ago received the name of "Buhrstone ore," but it is there also called Ferriferous ore. In Ohio it has a wide distribution and is known under several names, among which are "Baird" ore, "Gray" ore, "Limestone" ore.

The ore generally lies in immediate contact with the limestone, in a slab-like sheet one-half to 1 foot thick, but occasionally, as in Lawrence County, Pennsylvania, on the Houck farm, it locally thickens up to 20 feet, entirely replacing the underlying limestone, while again it is absent over wide areas, or represented by nodules scattered through the overlying shales. When the Ferriferous limestone is absent, its place in the series can often be correctly assigned from the existence of this ore, as is the case in Section 97, at Nuzum's Mills, West Virginia. This bed was formerly the main ore from which the charcoal furnaces of western Pennsylvania drew their supplies, and it is still the main feeder for these furnaces in southern Ohio. In northern West Virginia some iron ore occurs at this horizon in Monongalia and Preston Counties, and a few inches of it may be seen near the coke ovens on Glady Fork, below Thomas, Tucker County, but in the Great Kanawha region and southward toward the Big Sandy it appears to be completely absent as a distinct stratum, though nodules of iron sometimes come at this horizon.

THE FERRIFEROUS LIMESTONE.

The occurrence of the iron ore just described resting upon a bed of limestone over a wide area suggested the name "Ferriferous" which the early geologists applied to the limestone as well as the ore.

This is the most important and widely distributed limestone of the entire Coal Measure column, important both in an economic sense and as a stratigraphical horizon which with ordinary care can be unfailingly recognized by geologists as well as anyone else interested in determining the correct order of the rocks. It differs from the other limestones that we have had so far in the Lower Coal Measures, in being a genuine marine deposit, abounding in fossil crinoids, corals, brachiopods, lamellibranchs, univalves, etc., a list of the more common forms of which is given on pages 46 and 47, Report QQ, Second Geological Survey of Pennsylvania.

In Pennsylvania this limestone is confined to the counties west from Chestnut Ridge, attaining its maximum development in Clarion, Armstrong, Butler, Beaver, and Lawrence, where it is frequently 25 feet thick, or even more, and seldom less than 10 except it has locally thinned away entirely.

This limestone enters Ohio at Lowellville on the Mahoning River with a thickness of 15 feet, but westward it changes very much from its Pennsylvania type, becoming reduced in thickness, sometimes entirely absent, and occasionally splitting into two beds separated by 15 to 50 feet of shales, the lower one of which has been called the Putnam Hill limestone from its occurrence in an eminence of that name at

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Zanesville. In one way or another, however, it has been satisfactorily traced by Orton across the Ohio field to where it enters Kentucky from Hanging Rock.

A layer of flint or "buhrstone" is often incorporated with the top of this bed in Pennsylvania, and the same thing holds true for Ohio, but below this the rock is generally gray for 10 to 15 feet and of great purity, being especially prized as a flux in the smelting of iron ore, and used almost exclusively for this purpose in the Pittsburgh region. The lower portion of the stratum is generally of a bluish color, and its layers are shaly, being interstratified with thin films of clay and other impurities, and occasionally a distinct bed of shale separates the blue layers from the gray above. Hence it seems very probable that, as Prof. Orton once suggested, this shale layer probably increases in thickness through some regions of Ohio, thus separating the upper portion, as the "Gray" limestone, from the lower or blue part, which has been called the Putnam Hill. On one point, however, in this connection, the writer cannot fully agree with Prof. Orton, and that is concerning the presence of workable coal beds between these two divisions of the limestone. There is certainly none at Zanesville, the typical locality for the Putnam Hill limestone (Section 104), neither is there any at Shawnee (Section 105), nor at New Lisbon (Section 103), nor Sprucevale (Section 102), so that it appears more probable that the supposed workable coal between the two layers of the limestone is founded upon an error in identification.

Another characteristic of this limestone is that when it becomes thin and impure it almost always exhibits the "cone-in-cone" structure, though there are other horizons in the Coal Measures which show the same feature, notably the Mercer limestones.

The most northern point at which this limestone has been found in Pennsylvania is in the southern portion of McKean County, where Mr. Ashburner identifies with it a siliceous limestone occurring in the vicinity of Clermont.

In the North Potomac coal basin this limestone has been seen by the writer near Gorman, Garrett County, Maryland, and also below Thomas, along Glady Fork of Black Water. In each case, however, the deposit is entirely different from the marine type of western Pennsylvania and Ohio, and resembles more the fresh water limestones under the Freeport coals, since no marine fossils were observed at either locality; in fact there is no point in West Virginia or Maryland where the marine type of this limestone is known to exist, so far as the writer is aware.

Along the Great Kanawha River, in the vicinity of Cannelton, a bed of siliceous limestone occurs 75 to 100 feet under the Lower Kittanning coal, and it has been identified with the Ferriferous limestone horizon as shown in Section 115. It occasionally exhibits the "cone-in-cone" structure but is not fossiliferous.

Immediately under the Ferriferous limestone in western Pennsyl-

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vania there are often 5 to 10 feet of black fossiliferous shales, especially when the limestone is thin or locally wanting, so that the horizon can thus be frequently recognized without the presence of the limestone since the fossils in the shales are practically the same as in the latter.

THE CLARION COAL.

Mr. H. Martyn Chance has recently shown (VV, Second Geological Survey of Pennsylvania) that the coal bed which comes so close under the Ferriferous limestone in western Pennsylvania, and was formerly called the Scrub-grass coal, is really an off-shoot from the Clarion, and hence it is unnecessary to retain the name Scrub-grass, which should be replaced with Upper Clarion.

The main bench of the Clarion coal occurs through western Pennsylvania at an interval of 10 to 30 feet below the Ferriferous limestone. Its usual thickness is about 3 feet, though it often swells to 4 or 5. When well developed it generally contains one or two parting slates, and one of them thickening up causes the upper bench to approach the Ferriferous limestone, and it was then taken for a separate coal by the geologists of the First Pennsylvania Survey, but, as Chance suggests, this should be called the Upper Clarion bed in view of its origin. This upper member is thick enough to mine in only a limited area around the northern outcrop of the same in Clarion, Butler, and Jefferson Counties.

The Lower or main Clarion bed is of considerable importance in Pennsylvania, and generally furnishes some areas of good fuel in nearly every county where its outcrop occurs, though as a rule the coal is rather high in both ash and sulphur.

In eastern Ohio this bed acquires some importance in the vicinity of Leetonia and New Lisbon, and is there often parted by a vein of fire clay 1 to 4 feet thick, the upper coal alone being mined, and varying in thickness from 2½ to 3½ feet. Prof. Orton has also shown that the Canfield cannel of Mahoning County belongs to the horizon of the Clarion bed.

Westward from the eastern tier of Ohio counties, the Clarion coal disappears according to Orton and is of no more importance until Vinton and Jackson are reached, but this conclusion is based upon his present view of the Putnam Hill limestone, which he once regarded as a "split" from the Ferriferous of Pennsylvania, but which he now appears to reject, since he puts the Clarion coal between this latter limestone and the upper or "Gray" one, and identifies the coal underlying the Putnam Hill limestone as the Brookville bed of Pennsylvania. The writer has elsewhere expressed his doubt of the existence of any workable coal between these two limestones, believing that the identifications on which the conclusion was founded are erroneous, so that if we substitute Clarion coal for "Brookville" in Prof. Orton's Ohio series,

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all difficulties concerning the disappearance of the Clarion coal between eastern Ohio and Perry County vanishes, and the Clarion becomes one of the regular and persistent beds of the series clear across Ohio as it does in Pennsylvania. In the Zanesville section (104) the writer has indicated his views as to the equivalency of these members of the Ohio series.

The Clarion coal attains its maximum thickness in Stark County, Ohio, where it is 6 feet thick and a very fair steam coal, according to Orton.

In northern West Virginia this bed is generally present in the section, but is usually slaty and too impure to be valuable, so that it has never been mined in that part of the State.

Section near Eagle, Fayette County, West Virginia.—Along the Great Kanawha River a coal bed, which appears to come at this horizon, has been largely developed for coking purposes in the vicinity of Eagle, Fayette County, and hence is locally known as the Eagle vein. Where best developed there, it varies from 3½ to 4½ feet in thickness, and is a splendid coking coal, having the following structure in the vicinity of Eagle:

	Ft.	in.	Ft.	in.
Coal	1	2	4	9
Shale	0	3		
Coal	0	3		
Shale	0	3		
Coal	2	10		

In passing up the Kanawha from Eagle the upper shale parting of this bed gradually thickens till at the mouth of Armstrong Creek, 3 miles above, it becomes 20 feet thick and the coal has the structure given in Section 115.

The interval between this bed and the Lower Kittanning varies between 120 and 200 feet along the Great Kanawha, thickening up to the latter figures at Brownstown (Section 114), but southward from this in Wyoming County the interval swells still further to 230 feet in the vicinity of Oceana, as shown in Section 117, where the coal in question has a thickness of 5 to 6 feet and is known as the "coking" vein. There is evidently a wide area of this coal between the Kanawha and Big Sandy Rivers in which it will prove a valuable coking coal.

A bed of excellent fire clay often underlies the Clarion coal both in Pennsylvania and Ohio, being second in value only to the Kittanning clay above, and often rivaling it in thickness.

The interval below the clay down to the next coal bed (Brookville) varies greatly both in thickness and in the rock material which occupies it. Occasionally the series ends with the Clarion underclay, which rests immediately on top of the next lower or Conglomerate Measures, while again, shales and a sandstone termed by Chance the Clarion sandstone occupy this interval, which in Pennsylvania is seldom more than 30 to 50 feet thick.

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In Ohio the interval below the Clarion clay down to the top of the Pottsville Measures is seldom more than 30 feet, the same being true in northern West Virginia, as may be seen from Sections 96 and 97.

On the Great Kanawha River the interval from the Clarion or Eagle coal down to the top of the Pottsville Measures thickens to nearly 300 feet, and consists of a succession of shales and sandstones, in which occur two thin limestones and two or three thin coal beds. None of the latter attain a thickness of 3 feet, however, anywhere between the Kanawha and Big Sandy Rivers, so that the workable coals of this series in that region really end with the Clarion (Eagle) bed.

Two or three rocks in this interval of 300 feet in southwestern West Virginia require more particular notice. One of them, and the uppermost, is a very pure seam of coal, which at Eagle comes only 20 feet below the main Eagle bed, and is 1½ feet thick. I have termed it the Little Eagle coal, since it is possibly a "split" from the main bed above. To the south it appears to be quite persistent, since it occurs in Wyoming County in every section; but the interval separating it from the Eagle bed has there swelled to 65 feet (Section 117) and the coal has thickened to 27 inches of the same excellent fuel as on the Kanawha.

THE EAGLE LIMESTONE.

Another rock worthy of mention in this Kanawha series is an impure limestone which occurs near Eagle at an interval of 75 feet under the Eagle coal. It is only about 1 foot thick, quite dark, fossiliferous, and exhibits the "cone-in-cone" structure to a wonderful degree, being locally known as "black marble." The stratum is immediately underlaid by dark shales, which are crowded with marine fossils of the same type as those found in connection with the Ferriferous limestone in Pennsylvania and Ohio; in fact, so many of the species are identical, and the limestone itself so closely resembles the Ferriferous when thin, that sometimes I have been inclined to think that the two beds may possibly be identical, though this would seem to be impossible from the structure of Section 115, in which the whole lower coal series is exposed both above and below this stratum. If it should turn out to be identical with the Ferriferous, however, then the Eagle coal would be the Lower Kittanning, instead of the Clarion, and the Campbell's Creek bed the Middle Kittanning, or Nelsonville seam of Ohio, instead of the Lower Kittanning. The reader will understand the difficulty of correlation when he remembers that the lower coal series is less than 200 feet thick in the Hocking Valley, Ohio, while here, only 120 miles southward, the same series has swelled out to 1,000 feet.

The fossiliferous type of the limestone and its accompanying fossiliferous shale have never been seen by the writer, except in the vicinity of Eagle, and hence I have preferred to regard it as a local deposit below the horizon of the Ferriferous, since the fossils of the Lower Coal Measures have the same general facies at all horizons.

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THE BROOKVILLE COAL.

At the very base of the Lower Coal Measures, except the intervening underclay, there occurs in Jefferson, Clarion, and some other counties of Pennsylvania, a bed of usually slaty and otherwise impure coal, which was long ago named the Brookville bed, from its supposed occurrence near the town of that name in Jefferson County. This coal acquires some local importance around the northern margin of the coal field in Jefferson, Clarion, Butler, and Mercer Counties, but southward and westward it thins away and is often absent even as an impure bed, there being no coal whatever at this horizon where the Pennsylvania series enters Ohio; and if I am correct in identifying Prof. Orton's "Brookville" coal, (Vol. V, Ohio Geology) with the Clarion of Pennsylvania, then the Brookville coal is generally absent, or at least seldom workable anywhere in that State.

Very frequently the Brookville coal is represented in Pennsylvania by only a bed of black slate or coaly shale, resting on the top of the Conglomerate Measures, and this is the case in northern West Virginia, there being no workable coal at this horizon anywhere in that State, so far as the writer is aware. Even in the Kanawha field, where this lower portion of the column is so greatly thickened, the largest coal bed referable to the Brookville horizon is the one in the Wyoming County section (117), and this is only 22 inches.

On the Great Kanawha a bed of very bituminous shale (Section 115), from which lubricating oil was once manufactured, may possibly represent the Brookville coal horizon, since it is the lowest bituminous stratum in the series there.

Below this coal in Pennsylvania, and resting immediately on the top of the Conglomerate series, there is sometimes a good bed of fire clay, and Mr. Chance refers to this horizon the clay which is mined so extensively in Clearfield County, at Blue Ball, Wallaceton, and other points along the line of the Tyrone and Clearfield Railroad.

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CHAPTER VI.

THE POTTSVILLE CONGLOMERATE SERIES.

THICKNESS, CHARACTER, AND EXTENT.

Beneath the lowest member of the last described series there comes in a group of rocks (No. XII) which are nearly always so different from those in any other portion of the Carboniferous system that all geologists have regarded them as worthy of being placed in a distinct series. To this series several names have been given. The early geologists of Pennsylvania called it the "Seral" or "Great" Conglomerate, while in Virginia it has generally been named the No. XII Conglomerate, or simply No. XII. Prof. Lesley has in recent years, however, given it the geographical designation of Pottsville Conglomerate, from the great development of the series near the town of that name, while Prof. Fontaine, following the Pennsylvania custom of naming the several coal series after prominent rivers along which the beds are exposed, has suggested the name New River series, from that region of West Virginia where its coal beds attain a great development.

But since only one geographical name is admissible for the series, and as the term Pottsville is now so well ingrafted upon geological nomenclature through the numerous reports of the Second Geological Survey of Pennsylvania, it is thought best to retain it for the series, and at the same time retain New River for the name of the coal group which attains such prominence along that stream, thus putting it on a par with the Mercer group, which occurs in the upper portion of the series.

As exhibited everywhere in Pennsylvania and West Virginia, this series is very sharply set off from the Lower Coal Measures above and the Lower Carboniferous below, since in both cases there is a great change in the lithology, so that the geologist finds no difficulty in determining where the Pottsville series begins as well as where it ends.

The series as a whole possesses a large amount of hard, white, or grayish white sandstone, much of which is often conglomeritic. The sandstones are harder, more compact, and siliceous than any in the Lower Coal Series above. Bowlders of these sandstones take a smooth polish when rolled along river beds, but this is not the case with most sandrocks above this horizon.

The fossil contents are also different from those of any sandstones above, since here for the first time in descending the column of rocks

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do we find sigillariæ and the large lepidodendra very abundant in sandstones.

At the base of the series the change in lithology and life remains is even more abrupt, since with the disappearance of the white or gray sandstones and conglomerates, limestones, red shales, and green micaceous sandstones appear, in which plant remains are rare and the fossil trees are all small.

The Pottsville being composed mainly of very hard sandstones, the grains of which are cemented by silica and peroxide of iron, becomes almost indestructible by ordinary atmospheric influences, and has thus proved a most important factor in determining the topography of the Carboniferous system. Whenever these beds come to the surface in West Virginia and Pennsylvania, wild and rugged scenery is sure to be found. Rapid rivers, high waterfalls, great cliffs, and barren regions generally, mark the lines where these rocks emerge to daylight. The loftiest peaks of the Alleghany Mountains owe their origin to this friendly mantle, while its upturned edges have preserved many coal basins from complete destruction. The deep gorges, narrow cañons, and wild scenery of the Alleghany, Youghiogheny, Cheat, Monongahela, New, Guyandotte, and Big Sandy Rivers are all carved out of these rocks. The Falls of the Yough, Cheat, Tygart's Valley, Kanawha, and the "Roughs" of the Guyandotte and Big Sandy are all made by these same beds.

It was formerly supposed that a vast sheet of pebbly material underlaid all of the true Coal Measures, and that it was destitute of coal; but the recent work of the Second Geological Survey of Pennsylvania has shown that the series is very complex, consisting of several distinct sandstone members, between which occur shales, several coal beds, and occasionally some limestone.

In Ohio it happens that the upper members are not so massive as in Pennsylvania or West Virginia, while the coal beds which are prominent only around the margins are well developed there, so that the Ohio geologists have classed the upper portion with the Lower Coal Measures, and retained only the lowest member of the series, viz, a stratum termed the Sharon Conglomerate, as the representative of the whole series elsewhere. I shall show in the following pages that the whole series is easily recognized in Ohio, and that the western Pennsylvania type of these measures can be traced across Ohio, and hence for the sake of uniformity in nomenclature the Ohio geologists should cut off 100 to 150 feet from the bottom of their Lower Coal Measure column and combine it with the Sharon Conglomerate below, thus making several members for the series instead of a single stratum.

The coals of the Pottsville series, unlike those in the measures above, are persistent and valuable only around the margins of the Appalachian coal field, and for the most part only where their outcrops are above the level of the principal drainage streams, so that the conditions for-

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THE POTTSVILLE CONGLOMERATE TOPOGRAPHY IN BLACKWATER CANYON, TUCKER COUNTY, WEST VIRGINIA.

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merly supposed to apply to the Lower Coal Measures do actually prevail with reference to the coal in this series, since hundreds of carefully kept well records testify to the absence of any workable coal beds in this series over all except the outer rims of the Appalachian field. This same fact is visible to the eye in passing inward toward the center of the field down any one of the great rivers which drain into the Ohio. The Sharon coal disappears southward along the Shenango and Mahoning rivers long before its horizon dips down to water level; the New River coals fade out of the section before their outcrops touch the stream to the north; the great bed at Pocahontas does not extend indefinitely down the Guyandotte and Tug rivers, but only 20 to 30 miles, until it dwindles away to a bed too thin to mine, so that should a shaft be sunk to these beds 30 or 40 miles from their southern or northern outcrops respectively, the same massive, pebbly, white sandstones would be found, but instead of inclosing valuable coal beds they would hold only thin streaks of coal and some black slates.

Another peculiarity about these interconglomerate coals is the great difference in quality between those around the southern rim of the Appalachian field and those around its northern border, for in western Pennsylvania and across Ohio they are all open burning, hard, and generally known under the name of "block" coals, which can be used in furnaces in the raw state, while to the south, through West Virginia, Virginia, and on into Tennessee and Alabama, these same coals are very soft and tender, always cementing and making good coke. This difference is connected with different conditions of accumulation, there probably being less moisture in the great peat swamps at the north, and the vegetable accumulations taking place not under water, but partially at least in the open air. This much would be indicated by the innumerable films of mineral charcoal which characterize the northern coals and render them non-cementing. To the unequal rate of subsidence on the two sides of the Appalachian basin is doubtless owing the conditions which brought about the difference in the character of the coals.

Another peculiarity is the great purity of these early formed coals, their freedom from injurious quantities of ash and sulphur, both at the north and south. This also appears to be due to the conditions attending their deposition rather than to any difference in vegetable tissues, since just previous to the spread of these early coal marshes the whole Appalachian region was sheeted with a thick layer of clean gravel and white sand, thus effectually covering up the muddy deposits of a former epoch and causing the streams which drained into the peat bogs of that time to be pure and clear like our own mountain brooks of the present.

The thickness of the Pottsville series varies greatly in different portions of the Appalachian basin. In the bituminous regions of Pennsylvania, and everywhere in Ohio, they rarely exceed 300 feet and seldom go below 150; but southwestward through West Virginia they begin to swell out, reaching 700 feet at the head of Black Water, in

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Tucker County; 1,400 on the New River in Fayette, and probably 1,800 at the Kentucky line on the Tug River, in McDowell. Map Section C will exhibit the manner and rate at which these beds thicken southeastward from their northwestern outcrop in Ohio. The data for its construction were obtained from surface measurements and oil-well borings, several of which have been recently made along the Great Kanawha.

This series is also the repository of much salt water, as well as some oil and gas. The celebrated brines on the Great Kanawha, as well as at Pomeroy and many other localities along the Ohio River, come in its basal members, while the "first gas sand" of the Cannonsburg and Hickory region of Washington County, Pennsylvania, is found in the upper half of the same. This rock is also gas-bearing near Glover's Gap, on the Dodd farm, and near Mannington, Marion County, West Virginia, on the Snodderly farm.

We shall now give a number of sections in different portions of the Appalachian field, illustrating the character and thickness of the Pottsville series, and, as with the Lower Coal Measures, shall begin at the northeastern end of the field and proceed southwestward to the Kentucky line.

Section in Fox Township, Elk County, Pennsylvania.—The following section (Fig. 122) exhibits the structure of these beds in Fox Township, Elk County, Pennsylvania, as given by Ashburner (Report RR, p. 186, Second Geological Survey of Pennsylvania):

FIG. 122.—Section in Fox Township, Elk County, Pa.

Fox Township, Elk County, Pennsylvania.

[See map, D r.]

			Ft.	in.
1. Sandstone, Homewood			35	
2. Coal	Coal	1′ 2″	4	8
	Slate, black	0′ 3″		
	Coal	1′ 6″		
	Slate, black	0′ 3″		
	Coal	1′ 6″		
3. Slate and fire clay			15	
4. Coal	Coal	1′ 8″	5	11
	Slate	3′ 0″		
	Coal	1′ 8″		
5. Sandstone Conoquenessing			50	
6. Shale and slate			10	
7. Conglomerate			50	
8. Shales of No. XI				
Total			170	7

As will be observed, the series is thin in this region, and it seems to decrease still more in Tioga County further to the northeast, where it is less than 100 feet and all in one solid bed.

Section at Clearfield, Clearfield County, Pennsylvania.—At the town of Clearfield, in the county of the same name, a well was once bored for salt. It begins near the top of these measures, and the record shows the following structure (Fig. 123), as given in Report H, Second Geological Survey of Pennsylvania:

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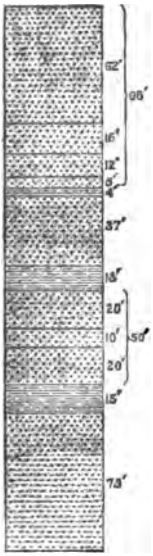

FIG. 123.—Section at Clearfield, Clearfield County, Pa.

Clearfield, Pennsylvania, from boring.

[See map, E s.]	Ft.	Ft.
1. Sandstone, ferruginous	62	
2. Sandstone, brown	16	96
3. Sandstone, light colored	12	
4. Sandstone, coarse, iron-stained	6	
5. Slate, black, mixed with sand		4
6. Sandstone, iron-stained, crumbly		37
7. Slate, soft gray		13
8. Sandstone, iron-stained, crumbly	20	
9. Sandstone, white	10	50
10. Sandstone, grayish white	20	
11. Slate, dark		15
12. Sandstone, light gray		73
13. Shales, and red beds of No. XI.		
Total		288

Section near Brookville, Jefferson County, Pennsylvania.—In the vicinity of Brookville, Jefferson County, Pennsylvania, these beds exhibit the following structure (Fig. 124), as learned from surface observations combined with the record of the Brookville Gas Company's well No. 2:

Brookville, Jefferson County, Pennsylvania.

[See map, E p.]	Ft.	in.
1 Sandstone, massive, Homewood	75	
2. Shales and sandstone	30	
3. Coal	0	2
4. Fire clay	5	
5. Sandstone, massive	70	
6. Concealed	10	
7. Sandstone, massive	90	
8. Slate	20	
9. Sandstone, hard	46	
10. Slate	4	
11. Sandstone, hard	22	
12. Red shales of No. XI.		
Total	372	2

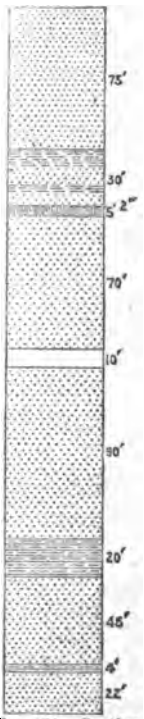

FIG. 124.—Section near Brookville, Jefferson County, Pa.

Here the series has thickened considerably, and the triple structure of its sandstones so often found in Pennsylvania becomes prominent. No. 4 appears to occupy the horizon of the Mount Savage fire clay.

Section near Patton Station, Red Bank Township, Clarion County, Pennsylvania.—Near Patton Station, Red Bank Township, Clarion County, Pennsylvania, the rocks of this series exhibit the following structure (Fig. 125), according to Mr. H. Martyn Chance (Report VV, p. 116, Second Geological Survey of Pennsylvania):

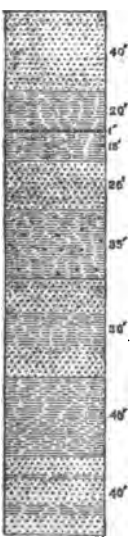

FIG. 125.—Section near Patton Station, Clarion County, Pa.

Patton Station, Red Bank Township, Clarion County, Pennsylvania.

[See map, E o.]	Feet.
1. Sandstone, hard, massive, Homewood	40
2. Shale, with a streak of coal	20
3. Iron ore bed	1
4. Shale	15
5. Sandstone	25
6. Shale, with kidney iron ore	35
7. Sandstone and shale	50
8. Shale, with sandy layers and ore balls	40
9. Sandstone, with interbedded thin shales	40
10. Red shale.	
Total	266

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Section at Kellersburg, Armstrong County, Pennsylvania.—Near Kellersburg, Armstrong County, Pennsylvania, these measures have the following structure (Fig. 126), according to Mr. William G. Platt (H 5, p. 194, Second Geological Survey of Pennsylvania):

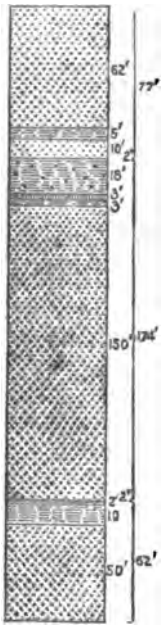

FIG. 126.—Section at Kellersburg, Armstrong County, Pa.

Section at Kellersburg, Armstrong County, Pennsylvania.

[See map, F o.]

	Ft.	Ft.	in.
1. Sandstone, massive, Homewood	62		
2. Shales	5	77	
3. Sandstone	10		
4. Coal (Mercer group)		0	2
5. Shales with iron ore	18		
6. Fire clay	3		
7. Shales	3	174	
8. Sandstone (Connoquenessing)	150		
9. Coal (New River group)		0	2
10. Clay	2		
11. Shales	10	62	
12. Sandstone	50		
Total		313	4

Here two prominent coal horizons are represented by mere streaks, the upper one being that of the Mercer group of western Pennsylvania and Ohio, while the lower is the Sharon coal horizon of the latter States and the New River group of West Virginia.

Section under Pittsburgh, Pennsylvania.—Under Pittsburgh, Pennsylvania, we learn the structure of this series from the careful record (Fig. 127) of the Jones & Laughlin gas well No. 2, as given in the Pennsylvania Geological Survey, 1886, p. 734:

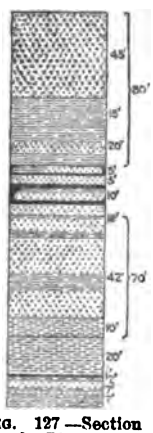

FIG. 127.—Section under Pittsburgh, Pa.

Under Pittsburgh, Pennsylvania; boring.

[See map, I m.]

	Feet.	Feet.
1. Sandstone, white, massive, Homewood	45	
2. Slate, black, trace of coal	15	80
3. Slate, dark, with sand shells	20	
4. Coal and slate, with white sandstone		5
5. Sandstone, grayish white, fine		5
6. Coal, coal slate, and white sandstone		10
7. Sandstone and black slate	18	
8. Sandstone, grayish white, slate in center	42	70
9. Sandy shale, dark	10	
10. Coal		Trace.
11. Sandy shale, dark		20
12. Coal		1
13. Sandy shale, dark		2
14. Sandstone and black slate		7
15. Slate, black, sandy, trace of coal		7
16. Limestone, Lower Carboniferous.		
Total		207

Section under Murraysville, Pennsylvania.—Under Murraysville, Westmoreland County, Pennsylvania, the structure is thus exhibited (Fig.

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128) by the record of the Philadelphia Company's gas well No. 49, McCutcheon farm, according to William S. Stevenson, assistant superintendent of the company:

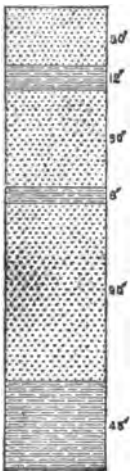

FIG. 128.—Section under Murraysville.

Under Murraysville, Westmoreland County, Pennsylvania (boring).

[See map, I n.]

	Feet.
1. Sandstone, gray, hard, close	30
2. Slate, black, soft	12
3. Sandstone, gray, hard, close	50
4. Slate, black, soft	8
5. Sandstone, gray, hard, close	90
6. Slate, black, soft	45
7. Red shale of No. XI.	
Total	235

Section under Washington, Pennsylvania.—Under Washington, Pennsylvania, the structure is thus given (Fig. 129) by Prof. Linton from the careful record he kept of the Thayer oil well (Geological Survey of Pennsylvania, p. 765, 1886):

Under Washington, Pennsylvania (boring).

[See map, J k.]

		Ft.	in.	Ft.	in.
1. Sandstone, Homewood	Sandstone, fine gray 9′; Sandstone, white micaceous 32′; Sandstone, white and dark mixed 17′; Sandstone, white, fine 29′			87	
2. Coal				1	6
3. Sandstone, white, hard, salt water		66	6		
4. Sandstone, fine, white and dark		15			
5. Shale, very dark, hard shells		13		110	6
6. Sandstone, white, fine		10			
7. Shale, black		4			
8. Sandstone, white, fine		2			
9. Shale, black, and coal				2	
10. Sandstone, close grained		1			
11. Shale and slate		13		29	
12. Shale and shells		15			
13. Shale, black, top of Lower Carboniferous beds.					
Total				230	

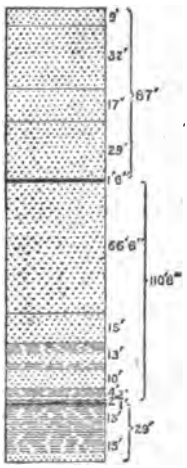

FIG. 129.—Section under Washington, Pa.

Here, as at Pittsburgh (Section 127), a careful record discloses thin representatives of the Mercer and New River coal groups Nos. 2 and 9, respectively.

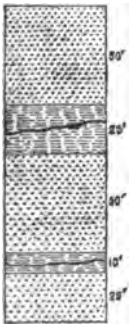

FIG. 130.—Section in Broad Top basin, Huntingdon County, Pa.

Section in Broad Top basin, Huntingdon County, Pennsylvania.—In the Broad Top basin of Huntingdon County, Pennsylvania, the structure of these beds is as follows (Fig. 130), according to Report T³, p. 69, Second Geological Survey of Pennsylvania:

Broad Top basin, Huntingdon County, Pennsylvania.

[See map, I t.]

	Feet.
1. Sandstone, slightly pebbly, Homewood	50
2. Shales, with a coal bed	25
3. Sandstone, pebbly	50
4. Shales, with a coal	10
5. Sandstone, pebbly	25
Total	160

The triple structure of the sandstones with intervening coal horizons is noteworthy here.

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Section near Wellersburg, Pennsylvania.—At the northern end of the Georges Creek or Cumberland coal basin, near Wellersburg, Somerset County, Pennsylvania, these beds show the following structure (Fig. 131) in the gap of Gladden's Run, through the easternmost ridge of the Alleghanies:

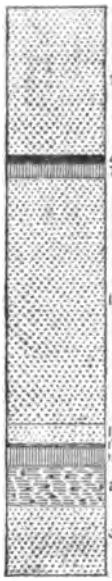

FIG. 131.—Section near Wellersburg, Pa.

Gladden's Run, Somerset County, Pennsylvania.

[See map, L q.]

	Ft.	in	Ft.	in.
1. Sandstone, massive, Homewood			75	
2. Coal, Mount Savage			4	
3. Fire clay, Mount Savage	7	6		
4. Sandstone, pebbly	125		143	6
5. Sandstone, dark, shaly	10			
6. Shale	1			
7. Coal: Coal	0'	1"	0	8
Slate	0'	4"		
Coal	0'	3"		
8. Fire clay, impure, sandy	10		65	
9. Shales, dark, with iron ore	20			
10. Sandstone, massive	35			
11. Red beds of No. XI.				
Total			288	2

This section shows the horizon of the famous Mount Savage fire clay to be in the Mercer coal group. No. 4 represents the Connoquenessing sandstones, while No. 7 is probably at the horizon of the Sharon coal.

Section near Piedmont and Westernport, Mineral County, West Virginia.—The Pottsville conglomerate beds thicken very rapidly in passing southward from the Pennsylvania line through Maryland and West Virginia along the Alleghany Mountain region. This is shown by the following section (Fig. 132), taken on the North Potomac, at Piedmont and Westernport, where that stream cuts through the East Front Ridge of the Alleghanies:

Near Piedmont, Mineral County, West Virginia.

[See map, N p.]

	Ft.	Ft.	in.
1. Sandstone, massive, Homewood		20	
2. Coal		2	
3. Shales, dark, containing fossil plants	45		
4. Sandstone, hard, massive	40		
5. Shales, and concealed	30	127	
6. Sandstone, flaggy	10		
7. Shale	2		
8. Coal		1	6
9. Fire clay, dark, sandy	12	22	
10. Sandstone, flaggy	10		
11. Coal		1	6
12. Shale, with nodular iron ore	2		
13. Shales and flaggy sandstone	40	87	
14. Sandstone, white, pebbly, very hard	45		
15. Shale, with streaks of coal		5	
16. Concealed shales and sandstones	145		
17. Sandstone, massive	10		
18. Shales, bituminous	10	195	
19. Sandstone, flaggy	10		
20. Sandstone, massive	20		
21. Coal		1	
22. Sandstone		4	
23. Fire clay and shale		3	
24. Sandy shales to top of No. XI red beds		4	
Total		473	

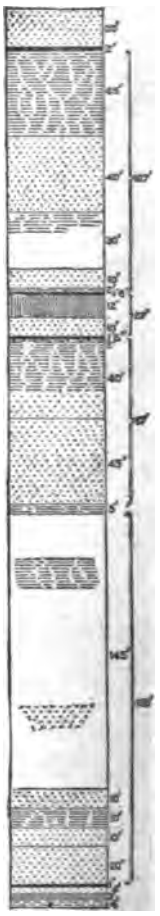

FIG. 132.—Section near Piedmont, Mineral County, W. Va.

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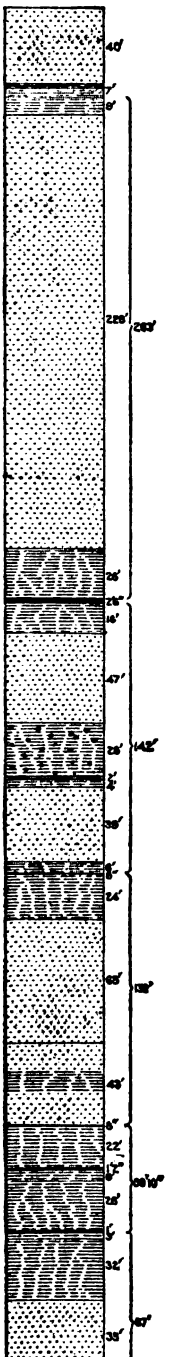

FIG. 133.—Section at mouth of North Fork of Black Water, W. Va.

Section on Black Fork of Cheat River, Tucker County, West Virginia.—In Tucker County, West Virginia, 50 miles south-southwest from Piedmont, in the gap made by the Black Fork of Cheat River through the central portions of the Alleghany Mountains, these beds exhibit a much greater thickness than at Piedmont, as will be seen by the following section (Fig. 133) made there by Mr. James Parsons, chief engineer of the West Virginia Central Railroad:

Mouth of North Fork of Black Water, Tucker County, West Virginia.

[See map, P o.]

		Ft.	in.	Ft.	in.
1.	Sandstone, Homewood			40	
2.	Coal, slaty and bituminous shale			7	
3.	Shale, dark	9			
4.	Sandstone, massive, pebbly	228		263	
5.	Brown shale	26			
6.	Coal (Nuttall)			2	6
7.	Shale, drab	16			
8.	Sandstone, massive	47			
9.	Shales with iron nodules	28			
10.	Fire clay	2		142	
11.	Shale	4			
12.	Sandstone, fine grained, flaggy	39			
13.	Shale	6			
14.	Coal			0	6
15.	Shale	24			
16.	Sandstone, massive	65		132	
17.	Sandstone and shales	43			
18.	Coal	0	8		
19.	Shale, brown	22			
20.	Coal	1	2		
21.	Bituminous shale, with coal streaks	6		59	10
22.	Brown shale	26			
23.	Coal	1			
24.	Bituminous shale, with coal streaks	3			
25.	Shale	32			
26.	Sandstone, massive	35		87	
27.	Shale, brown	20			
28.	Red beds, top of No. XI.				
	Total			733	10

Here we find the entire interconglomerate coal group represented. No. 2 comes apparently at the Mercer horizon and is the "Railroad" vein along the Potomac.

No. 6 comes at the horizon of the Nuttall bed of New River, while Nos. 14 to 24 represent the lower ones along that stream as well as the great Pocahontas vein of McDowell and Mercer Counties, West Virginia.

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Section near Rowlesburg, West Virginia.—A fine section of the Conglomerate coals is exposed in the cuts of the Baltimore and Ohio Railroad, near the summit of Cheat River grade, 4 miles west from Rowlesburg, Preston County, West Virginia (Fig. 134):

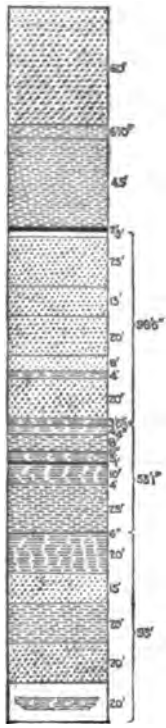

FIG. 134.—Section near Rowlesburg, W. Va.

Along the Baltimore and Ohio Railroad, Cheat River grade, four miles west from Rowlesburg, Preston County, West Virginia.

[See map, N n.]		Ft.	in.	Ft.	in.
1. Sandstone, massive, coarse, yellowish, Homewood				60	
2. Coal	Coal 0′ 5″; Shales, sandy 6′ 0″; Coal 0′ 5″			6	10
3. Shales, brown, sandy				45	
4. Coal, slaty				2	
5. Shales		3			
6. Sandstone, massive		25			
7. Sandstone, flaggy		15			
8. Sandstone, massive, grayish white		20		98	6
9. Sandstone, flaggy		8			
10. Shales, brown		4			
11. Sandstone, grayish white		20			
12. Shale, brown		3	6		
13. New River coal beds	Coal 0′ 5″; Shale, gray 4′ 0″; Coal 0′ 4″; Shales, drab, sandy 8′ 0″; Iron ore 0′ 6″; Shales 5′ 0″; Coal 1′ 0″; Shales 10′ 0″; Coal 0′ 4″; Shales, brown, sandy 25′ 0″; Coal 0′ 6″			55	1
14. Shales, brown		20			
15. Sandstone		15			
16. Shales, buff, sandy		20		95	
17. Sandstone, massive, pebbly		20			
18. Concealed, and shales		20			
19. Top of No. XI, red shales.					
Total				362	5

Nos. 2 and 4 represent the Mercer coal group, Nos. 6 to 12 the Connoquenessing sandstones, while No. 13 represents the New River coal group.

Section near mouth of Sandy Creek, Preston County, West Virginia.—Farther northwest, down Cheat River, and in the center of the Ligonier basin, the Pottsville series exhibits the following structure (Fig. 135) near the mouth of Sandy Creek, Preston County, West Virginia:

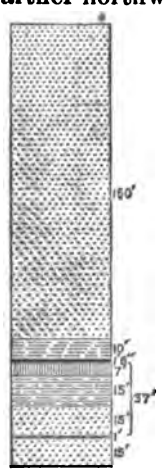

FIG. 135.—Section near mouth of Sandy Creek, Preston County, W. Va.

Near mouth of Sandy Creek, on Cheat River, Preston County, West Virginia.

[See map, M m.]		Ft.	Ft.	in.
1. Sandstone, massive, very pebbly near middle			160	
2. Shales, dark			10	
3. Coal	Coal 0′ 10″; Shale 0′ 3″; Coal 0′ 5″		1	6
4. Fire clay		7		
5. Slate, black, fissile		15	37	
6. Sandstone, gray		15		
7. Shale, with streak of coal			1	
8. Sandstone, grayish white			15	
9. Green and red shales of No. XI.				
Total			224	6

Here, as frequently happens, the Mercer coal group disappears entirely, while the Homewood and Connoquenessing sandstones unite into one solid mass. Nos. 3 to 7 represent the New River coal group.

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Section on Booth's Creek, Taylor County, West Virginia.—The structure of the Pottsville beds in the region along the line between Taylor and Marion Counties, West Virginia, is learned from a boring made for oil on Booth's Creek, Taylor County, by Mr. John L. Steele, to whom I am indebted for the following record (Fig. 136):

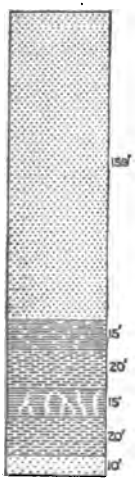

FIG. 136.—Section on Booth's Creek, Taylor County, W. Va.

Booth's Creek, Taylor County, West Virginia (boring).

[See map, O l.]

	Ft.
1. Sandstone, hard, white, pebbly	150
2. Black slate	15
3. Shale, gray and sandy	20
4. Shale, black	15
5. Shale, gray, sandy	20
6. Sand, gray, pebbly	10
7. Red beds of No. XI.	
Total	239

Here the structure is very much like that of the previous section on Cheat River, and the thickness is also nearly the same.

Section under Clarksburg, West Virginia.—Under Clarksburg, Harrison County, West Virginia, the succession is given as follows (Fig. 137), from the record of the Despard gas well, on the authority of Prof. T. M. Jackson:

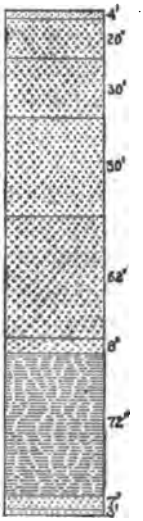

FIG. 137.—Section under Clarksburg, W. Va.

Clarksburg, West Virginia (gas well).

[See map, O k.]

	Ft.	Ft.
1. Sandstone, black	4	
2. Sandstone, white	20	
3. Sandstone, gray	30	174
4. Sandstone, white	50	
5. Sandstone, gray	62	
6. Sandstone, dark	8	
7. Shale, black		72
8. Sandstone, white		7
9. Sandstone, gray		3
10. Red beds of No. XI.		
Total		256

Section near Farmington, West Virginia.—Under the central portion of Marion County, West Virginia, the structure is shown by the record of the Hukill oil boring near Farmington (Fig. 138), as given in Second Geological Survey of Pennsylvania, 1886 (pp. 782, 783):

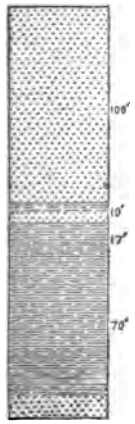

FIG. 138.—Section near Farmington, W. Va.

Farmington, West Virginia (oil boring).

[See map, M l.]

	Ft.
1. Sandstone	100
2. Shell	10
3. Slate	17
4. Black slate	70
5. Sandstone	12
6. Red beds of No. XI.	
Total	209

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Section under Wellsburg, West Virginia.—Under Wellsburg, Brooke County, West Virginia, the Barclay gas well No. 1 gives the following (Fig. 139) for these beds on the authority of Mr. Barclay:

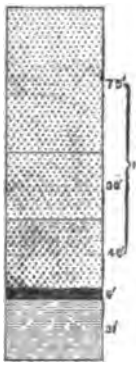

FIG. 139.—Section under Wellsburg, W. Va.

Wellsburg, West Virginia (gas boring).

[See map, J j.]

	Ft.	Ft.
1. Sandstone, white	75	
2. Sandstone, gray	30	145
3. Sandstone, blue	40	
4. Coal		6
5. Slate and shale		31
Total		182

The coal reported in this section comes at the horizon of the Sharon bed of Ohio and Pennsylvania, but it was probably nearly all coaly slate or else a local thickening, since other borings put down in this region do not report it at all.

Section in Mercer County, Pennsylvania.—Along the northwestern margin of the Appalachian field in the counties of Lawrence and Mercer, bordering the Ohio State line, a series of workable coal beds make their appearance in the Pottsville series and extend along the margin of the field clear through to southern Ohio. The general section of the Pottsville series of Mercer County, Pennsylvania, given in Q³ (p. 33), Second Geological Survey of Pennsylvania, shows the succession of these coal groups as follows (Fig. 140):

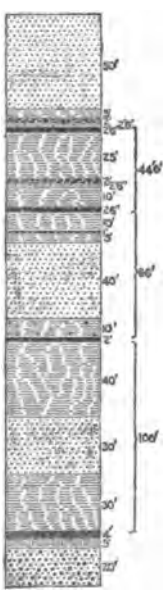

FIG. 140—Section in Mercer County, Pa.

Mercer County, Pennsylvania.

[See map, E k.]

	Ft.	in.	Ft.	in.
1. Sandstone, Homewood			50	
2. Shales			5	
3. Iron ore			2	
4. Limestone, Mercer, Upper			2	6
5. Coal, Mercer, Upper	2	6		
6. Shales	25			
7. Iron ore	2			
8. Limestone, Mercer, Lower	2	6	44	6
9. Shales	10			
10. Coal, Mercer, Lower	2	6		
11. Shales	10			
12. Iron ore	1			
13. Shales	5		66	
14. Sandstone, Connoquenessing, Upper	40			
15. Shales with iron ore	10			
16. Coal, Quakertown			2	
17. Shales	40			
18. Sandstone, Connoquenessing, Lower	30		100	
19. Shales, Sharon, iron bearing	30			
20. Coal, Sharon			4	
22. Fire clay and shales			5	
23. Sharon Conglomerate, base of No. XII			20	
Total			301	

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Section near Quakertown, Mahoning County, Ohio.—Where the Ohio-Pennsylvania State line crosses the Mahoning River, near Quakertown, these beds exhibit the following structure (Fig. 141):

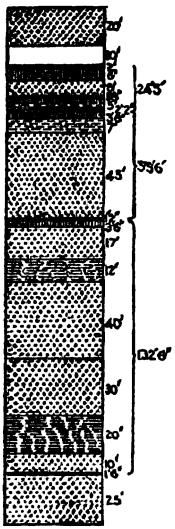

FIG. 141.—Section near Quakertown, Ohio.

Ohio-Pennsylvania line on Mahoning River.

	[See map, F k.]	Ft. in.	Ft. in.
1.	Homewood sandstone		20
2.	Concealed		10
3.	Limestone, Upper Mercer	2	
4.	Fire clay	6	
5.	Sandstone, shaly	8	
6.	Coal, slaty, Middle Mercer	1 3	
7.	Fire clay and sandy shales	5	24 5
8.	Limestone, Lower Mercer	1	
9.	Shales	0 6	
10.	Coal, Mercer, Lower	0 8	
11.	Fire clay	3 6	
12.	Shales, sandy	7	55 6
13.	Sandstone, Connoquenessing, Upper	45	
14.	Coal, Quakertown		1 2
15.	Fire clay and shales	3 6	
16.	Sandstone, Connoquenessing, Lower: Sandstone 17′; Shales 12′; Sandstone, flaggy 40′; Sandstone, massive 30′	99	132 6
17.	Blue shales, with iron ore balls	20	
18.	Sandstone, massive	10	
19.	Coal, Sharon, and bituminous slate		1 6
20.	Sandstone, flaggy, to base of No. XII		25
	Total		270 1

The Sharon coal of these sections (140, 141) represents the New River coal group of West Virginia, since the Mercer group above does not furnish valuable coal in that region, but only thin slaty beds.

Section in Holmes County, Ohio.—In Holmes County, Ohio, these beds are given as follows (Fig. 142), in Vol. V, Ohio Geology, p. 837:

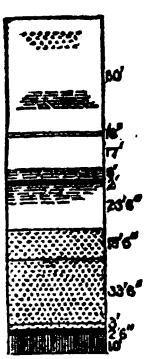

FIG. 142.—Section in Holmes County, Ohio.

Holmes County, Ohio.

	[See map, H e.]	Ft. in.
1.	Interval, sandstone and shales	60
2.	Limestone, Lower Mercer	1 6
3.	Coal, Lower Mercer	
4.	Concealed	17
5.	Gray shales	6
6.	Coal	2
7.	Gray shale and concealed	23 6
8.	Sandstone, Upper Connoquenessing	15 6
9.	Coal, Quakertown	blossom
10.	Sandstone, shaly, Lower Connoquenessing	33 6
11.	Coal, thin	
12.	Sandstone	3
13.	Coal, Sharon	2 6
14.	Fire clay	10
15.	Lower Carboniferous beds.	
	Total	174 6

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Section in Washington County, Ohio.—In Washington County, Ohio, the Pottsville measures are given as follows (Fig. 143) by Mr. F. W. Minshall, from the record of the Epler oil boring:

FIG. 143.—Section in Washington County, Ohio.

Epler oil boring, Washington County, Ohio.

[See map, M g.]

	Ft.
1. Sandstone	24
2. Shales	20
3. Coal	
4. Shales	70
5. White, pebbly sandstone	60
6. Black shales	4
7. Lower Carboniferous beds.	
Total	178

Section at Parkersburg, West Virginia.—The Camden Consolidated Oil Company, in boring at Parkersburg, West Virginia, found the following structure (Fig. 144), according to Mr. R. A. Cole, the superintendent:

Parkersburg, West Virginia (boring).

[See map, O f.]

	Ft.
1. Shales, gray	110
2. Sandstone, hard, white	50
3. Slate, black	25
4. Sandstone, hard, gray	50
5. Shales of No XI.	
Total	235

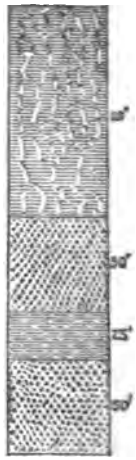

FIG. 144.—Section under Parkersburg, W. Va.

Section near Burning Springs, West Virginia.—Near Burning Springs, Wirt County, West Virginia, these same beds have this succession (Fig. 145), as found in the Simpson oil boring by Mr. Minshall:

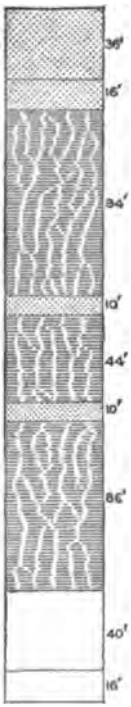

FIG. 145.—Section near Burning Springs, W. Va.

Simpson well, Wirt County, West Virginia.

[See map, P g.]

	Ft.
1. Sandstone	36
2. Coal	
3. Sandstone	16
4. Shales	94
5. Coal	
6. Sandstone	10
7. Shales	44
8. Sandstone	10
9. Shales	86
10. Coal	
11. Conglomerate	40
12. Shales	16
13. Limestone, Subcarboniferous.	
Total	352

The Burning Springs section (Fig. 145) shows a rapid increase in the thickness of these beds towards the southeast, since they are just twice as thick here as in Washington County, Ohio (Section 143), 50 miles distant.

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Section near Jackson Furnace, Jackson County, Ohio.—In Jackson County, Ohio, the Pottsville series has the following structure (Fig. 146) near Jackson furnace, as given in the Ohio Geological Survey, 1870 (p. 158):

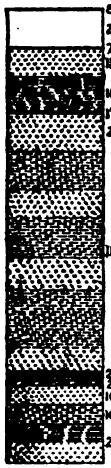

FIG. 146.—Section near Jackson Furnace, Jackson County, Ohio.

Jackson Furnace, Jackson County, Ohio.

[See map, P b.]

	Ft.	in.
1. Iron ore	0	8
2. Interval	20	
3. Iron ore	0	7
4. Coarse sandstone	15	
5. Coal	trace	
6. Shale	18	
7. Iron ore	0	6
8. Clay, shale	1	
9. Sandstone, coarse	20	
10. Sandy shales and laminated sandstone	115	
11. Coal	2	6
12. Fire clay	2	6
13. Clay, shale	2	6
14. White sandstone	10	
15. Sandy shale	10	
16. Coal	0	4
17. Shales and sandstones to base of No. XII	20	
Total	238	7

Section at Hanging Rock, Sciota County, Ohio.—In the vicinity of Hanging Rock, Ohio, the Pottsville series has the following structure (Fig. 147):

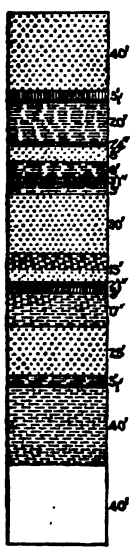

FIG. 147.—Section at Hanging Rock, Sciota County, Ohio.

Hanging Rock, Sciota County, Ohio.

[See map, R a.]

		Ft.	in.
1. Sandstone, massive		40	
2. Fire clay		5	
3. Limestone and iron ore, Upper Mercer		1	
4. Shales		20	
5. Coal, Upper Mercer		0	4
6. Fire clay, sandy		2	
7. Sandstone, shaly		8	
8. Shales, drab		8	
9. Coal, Lower Mercer	Coal 0′ 5″; Fire clay 1′ 4″; Coal 1′ 4″	3	1
10. Fire clay and shales		5	
11. Sandstone, Connoquenessing, Upper, massive, coarse, yellowish		30	
12. Sandy shales and shaly sandstone		15	
13. Coal, Quakertown	Coal 0′ 5″; Slate 0′ 3″; Coal 1′ 5″	2	1
14. Fire clay		3	
15. Sandy shales		17	
16. Sandstone, Lower Connoquenessing, massive		25	
17. Shales, dark blue, with iron ore		5	
18. Iron ore, sandy		1	
19. Blue sandy shales		40	
20. Interval to base of Pottsville beds under river, from drill hole (E. B. Willard)		40	
Total		270	6

Here the Mercer group, together with the Quakertown coal, is distinctly recognizable at the very southern border of Ohio, while the Connoquenessing sandstones and the dark blue Sharon iron-bearing shales below look exactly like the same beds in eastern Ohio. The base of the series was given me here from the record of a bore-hole put down by Mr. E. B. Willard, superintendent of the Hanging Rock Coal Company.

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Section on Big Sandy River, Lawrence County, Kentucky.—Twenty miles up the Big Sandy River, and near the mouth of Blaine Creek, the succession of the series is as follows (Fig. 148) according to the record of Rigdon gas well No. 2, as furnished by Mr. F. H. Oliphant:

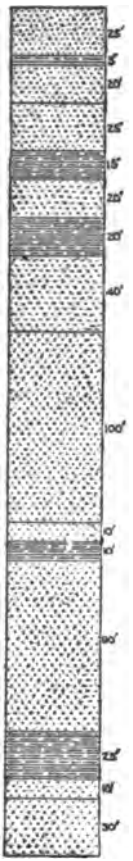

FIG. 148.—Section under Big Sandy River near mouth of Blaine Creek.

Under Big Sandy River at mouth of Blaine Creek (boring).

[See map, V b.]

		Ft
1.	Sandstone, white	25
2.	Slate, black	5
3.	Sandstone, white	20
4.	Sandstone, dark gray	25
5.	Slate, gray	15
6.	Sandstone, dark	20
7.	Slate, gray	20
8.	Sandstone, dark gray	40
9.	Sandstone, white, salt water	100
10.	Sandstone, dark blue	10
11.	Slate, black	10
12.	Sandstone, white	90
13.	Slate, black	25
14.	Shells	10
15.	Sandstone, hard blue	30
16.	Limestone, Lower Carboniferous.	
	Total	445

This section exhibits the beginning of the great southeastern thickening of the Pottsville series along the Big Sandy, but we have not sufficient data southward from Blaine Creek to trace the rate of increase along the Tug Fork, since even the top of the Pottsville does not rise to daylight on that stream for 100 miles above the mouth of Blaine. When the bottom series does finally come to the surface at the southern edge of McDowell County, West Virginia, it is not less than 1,500 feet thick, and may possibly be 2,000, since the Kentucky geologists claim the latter thickness for these measures on the headwaters of the Big Sandy.

There is no point along the Tug River in West Virginia where a vertical measurement can be made; hence, if the exact thickness is ever determined it must be by a boring.

The black slates, Nos. 2, 11, and 13 of the above section, probably represent the interconglomerate coal beds.

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Section under Charleston, Kanawha County, West Virginia.—On the Great Kanawha River some recent borings for gas have supplied the necessary data there, thus giving measurements at two points before the whole formation comes to the surface. The first one of these is the record of the Edwards gas well No. 3, bored at Charleston, West Virginia, which gives the following structure (Fig. 149) for these beds, according to Mr. William S. Edwards:

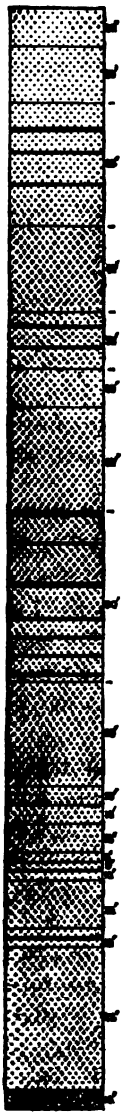

FIG. 149.—Section under Charleston, Kanawha County, W. Va.

Under Charleston, Kanawha County, West Virginia (boring).

[See map, T f.]

	Ft.
1. Sandstone	20
2. White sandstone	30
3. Hard sandstone and shells	65
4. White sandstone	45
5. Black sandstone and shells	30
6. White sandstone	20
7. Hard sandstone	55
8. Hard black shells and gas	90
9. White sandstone	55
10. Black sandstone	10
11. White sandstone	10
12. Black sandstone	15
13. White sandstone	5
14. Hard shells	10
15. White sandstone	25
16. Sandshell, hard	10
17. White sandstone	75
18. Black sand	10
19. Lower Carboniferous limestone.	
Total	580

Here the Pottsville series has thickened to about three times its size at the northwestern outcrop of these beds in Ohio, 100 miles distant. Whether the thickening is gradual or abrupt is not known, and can not be until more borings are made. It is probably gradual from the center of the great Apalachian trough, 50 miles northwest of Charleston.

The interconglomerate coal beds appear to be entirely absent from the above section, since not even black slates are present according to the driller's record.

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Section at Burning Spring, Kanawha County, West Virginia.—At Burning Spring, 9 miles south from Charleston, the record of Edwards gas well No. 1 gives these beds as follows (Fig. 150):

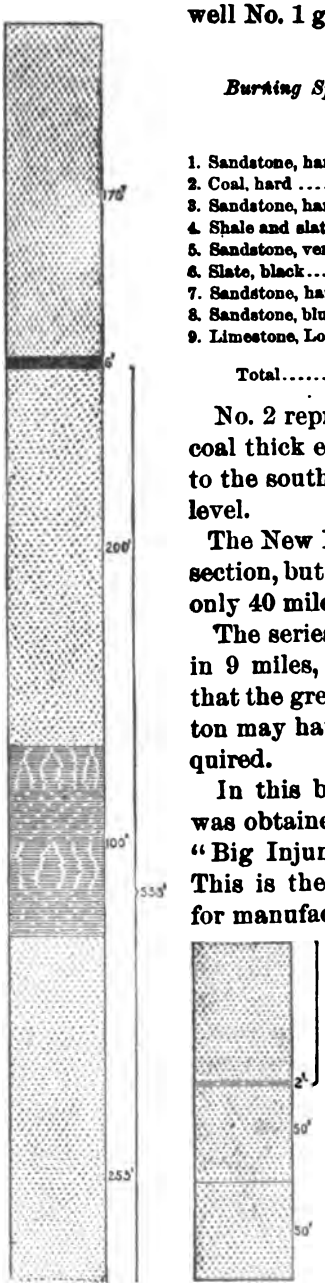

FIG. 150.—Section at Burning Spring, Kanawha County, W. Va.

Burning Spring, Kanawha County, West Virginia (boring).

[See map, T f.]

	Ft.	Ft.
1. Sandstone, hard white		176
2. Coal, hard		6
3. Sandstone, hard white, salt water	200	
4. Shale and slates, light colored	100	555
5. Sandstone, very hard and white, with salt water	255	
6. Slate, black		2
7. Sandstone, hard white		50
8. Sandstone, blue hard		50
9. Limestone, Lower Carboniferous		
Total		839

No. 2 represents the Mercer coal group, though no coal thick enough to mine ever occurs at this horizon to the southward, where these beds rise above water level.

The New River coals belong in Nos. 4 and 6 of the section, but they here contain no coal whatever, though only 40 miles north from the New River coal field.

The series has here increased 259 feet in thickness in 9 miles, a very rapid rate, and possibly indicating that the great thickness (580 feet) found under Charleston may have been abruptly instead of gradually acquired.

In this boring a considerable flow of natural gas was obtained in the top of the Pocono sandstone, or "Big Injun" oil sand, at a depth of about 1,000 feet. This is the locality where natural gas was first used for manufacturing purposes in the United States, as far back as 1841. It was utilized for evaporating salt water. One of the gas wells found here, according to report, displaced for fuel 2,000 bushels of coal daily during a period of ten years. The last well, however (bored in 1887), does not produce much over 500,000 cubic feet of gas daily. The most productive wells were situated near the crest of the anticline which crosses the Kanawha River at Burning Spring.

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Section near Nuttallburg, Fayette County, West Virginia.—Passing on southward up the Kanawha and New Rivers, there is no opportunity to get another measurement of the Pottsville series until all of its members have risen above the level of New River, in the vicinity of Nuttallburg, Fayette County, West Virginia, 50 miles distant from Burning Spring, where the following succession occurs (Fig. 151):

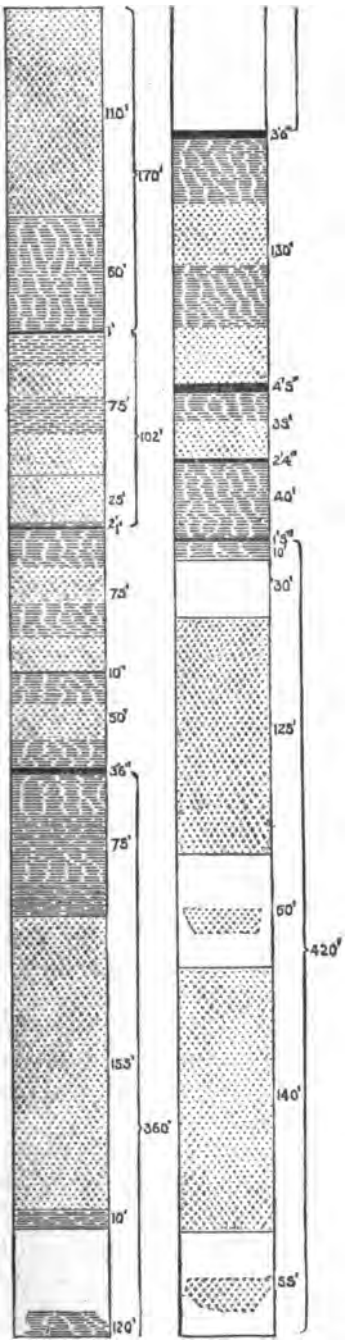

FIG. 151.—Section in vicinity of Nuttallburg, Fayette County, W. Va.

Vicinity of Nuttallburg, Fayette County, West Virginia.

[See map, U h.]

	Ft.	Ft.	in.
1. Sandstone, massive, pebbly, Homewood	110	170	
2. Shales	60		
3. Coal		1	
4. Sandy shales and sandstone	75	102	
5. Sandstone	25		
6. Black slate	2		
7. Coal		1	
8. Shales and sandstone		75	
9. Coal		0	10
10. Shales, sandstone and shales		50	
11. Coal, Nuttall		3	6
12. Shales and slates	75	360	
13. Sandstone, massive	155		
14. Slates, dark	10		
15. Concealed, and shales	120		
16. Coal, Fire Creek		3	6
17. Shales and sandstone		130	
18. Coal, Quinnimont (?) { Coal 1' 0", Slate 0' 3", Coal 2' 0", Slate 0' 2", Coal 1' 0" }		4	5
19. Shales and sandstone		35	
20. Coal, slaty		2	4
21. Shales		40	
22. Coal		1	5
23. Shales	10	420	
24. Concealed	30		
25. Sandstone, massive	125		
26. Concealed, and sandstone	60		
27. Sandstone, massive	140		
28. Concealed, and sandstone to top of No. XI shales	55		
Total		1,400	0

No. 11, the Nuttall coal, is the highest member of the New River group that ever furnishes valuable coal along that stream. Its place in the Pottsville series is 400 feet below the top, and the other thin coals above it belong to the Mercer group.

Whether No. 18 is identical with the Quinnimont, or whether this latter coal is the same as the Fire Creek, No. 16, are questions yet unsettled.

Just what represents the Pocahontas coal of McDowell and Mercer Counties in this section, or whether it is represented at all is uncertain, but No. 18 may possibly come at that horizon.

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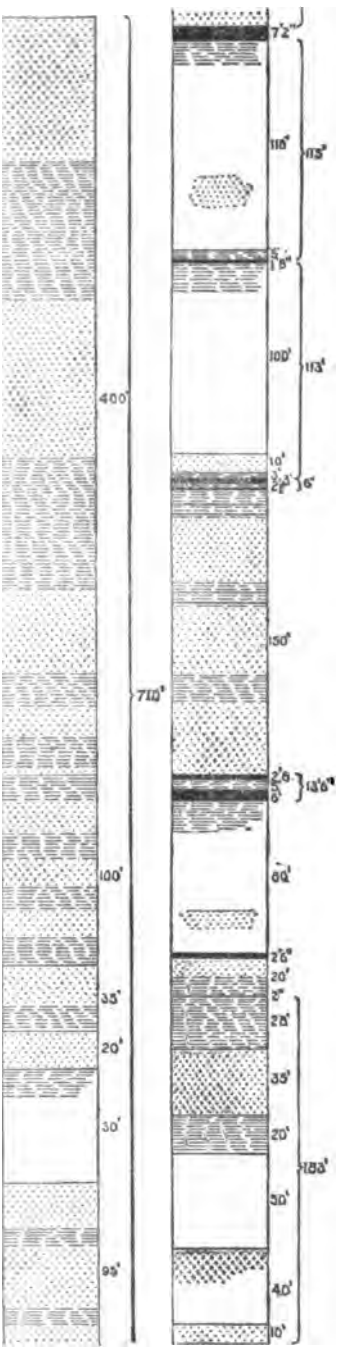
Section on Crane Creek, Mercer County, West Virginia.—At the ex-ɔme southern edge of the Appalachian field in Mercer County, West Virginia, the following section (Fig. 152) of the Pottsville series was obtained upon the waters of Crane Creek by adding 400 feet to the summit of the column for the estimated thickness of beds removed by erosion:



ɔ. 152.—Section on Crane Creek, Mercer County, W. Va.

Crane Creek, Mercer County, West Virginia.

[See map, Y g.]		Ft.	Ft.	in.
1. Sandstones and shales, here eroded from top of No. XII (estimated)		400		
2. Shales and sandstones		100		
3. Sandstone and shales		35	710	
4. Sandstone, gray		20		
5. Shales, and concealed		60		
6. Sandstone, massive, and shales		95		
7. Coal	Coal 0′ 2″; Shales 2′ 6″; Coal 2′ 4″; Shale 0′ 6″; Coal 1′ 8″		7	2
8. Shales, sandstone, and concealed		110	115	
9. Shales		5		
10. Coal, good			1	8
11. Shales, and concealed		100	113	
12. Sandstone		10		
13. Shale		3		
14. Coal	Coal 3′; Shale 2′; Coal and slate 1′		6	
15. Concealed, with shales, sandstones, and two thin coals			150	
16. Coal, Pocahontas (No. III)	Coal 2′ 6″; Shale 5′ 0″; Coal 6′ 0″		13	6
17. Shales, sandstone, and concealed			80	
18. Coal (No. II)			2	6
19. Sandstone and shales			20	
20. Coal (No. I)			0	2
21. Shales		28	183	
22. Sandstone, gray		35		
23. Shales, dark		20		
24. Concealed		50		
25. Sandstone, and concealed		40		
26. Sandstone, gray, massive		10		
27. Green, limy, fossiliferous shales, top of Lower Carboniferous.				
Total		1,402		

The interval added to the top of the Pottsville in this section is only an estimate at best, and the amount may not be near large enough, since the Kentucky geologists report the series as 2,000 feet thick not many miles southwest from this region.

The separate coal beds of this section can not yet be satisfactorily correlated with those on New River (Section 151). At one time the writer was inclined to believe that No. 7 might be the equivalent of the Nuttall vein, and that No. 16 of this section was probably identical with No. 18 of the Nuttallburg section

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(151), but the Pocahontas coal lies 200 feet nearer the base of the Pottsville series than No. 18 does on New River, and hence unless this part of the series thins away towards the southwest, which seems improbable, the possibility of identity is rather slender. The mining operations of the next few years, however, may be depended upon to settle the question, since it has a more than scientific interest.

A cursory examination of the sections given will show that the Pottsville series generally has something like the following structure:

Sandstone (Homewood).
Coal group (Mercer).
Sandstones (Connoquenessing).
Coal group (New River).
Sandstone (Sharon).

Of course when the series attains such an excessive thickness as on the New River, for instance, the structure is more complicated than the above scheme would indicate, and yet even then a general agreement can usually be made out.

Having now glanced at the general structure of these measures, we shall take up the more important members and describe them in detail.

CHARACTERISTIC HORIZONS.

THE HOMEWOOD SANDSTONE.

The Pottsville series is nearly everywhere capped with a coarse sandstone, which is quite different in texture and general appearance from any of the sandstones in the Coal Measures above. In the vicinity of Homewood, Beaver County, Pennsylvania, this rock attains a thickness of 150 feet, and was named from that locality. It is generally quite massive, making great cliffs along the streams and covering the summits with huge blocks arranged in "rock cities." While usually quite hard, it generally splits well and makes excellent building stone, the blocks from it being almost indestructible. Although generally of a yellowish or buffish gray tinge, it occasionally consists of almost pure white quartz grains, and hence sometimes supplies glass sand of excellent quality. This might be called the "cascade" member of the Pottsville series, since it so often produces water-falls.

In Pennsylvania it is generally 30 to 50 feet thick, but occasionally, as at Homewood and other points, it thickens up to 75 or even 150 feet.

Westward, in Ohio, the rock thins down and is often only 15 to 20 feet thick, but still distinctly recognizable as a heavy bedded, coarse sandstone, filled with fossil stems and trunks of trees, mostly lepidodendron and sigillaria. It is seen in the bed of Little Beaver near its mouth, and frequently between that point and Fredericktown. It is the quarry rock in Coshocton County referred to in Vol. V (p. 104), Ohio Geology, where it is 30 feet thick and of the same type so often found in Pennsylvania. From this point on across Ohio, to Ironton and

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Hanging Rock, it is frequently seen, and at the latter point makes one of the great cliffs in the steep hillside which gave name to the place, being there 40 feet thick.

Along the Great Kanawha this rock comes to water level at the mouth of Armstrong Creek, and from there on up that stream, as well as up the New and Gauley rivers, is a great cliff rock 150 to 200 feet thick. It crowns the walls of the New River cañon at Hawk's Nest and other points to Nuttallburg and beyond, where it seems to change suddenly in character southward from that, becoming soft and easily disintegrating to a heap of coarse, brown sand.

On the Tug fork of Big Sandy this stratum makes great cliffs along the hills through the "roughs" of Tug, and sinks below that stream at the mouth of Ben's Creek, 95 miles above Louisa.

Ohio Pyle Falls, on the Youghiogheny River, is made by this rock, and the upper portions of the great cascades on the Black Water and Glady forks of Cheat pour over the same stratum.

It is the gas-bearing member in western Pennsylvania and northern West Virginia.

THE MERCER GROUP.

In western Pennsylvania a group of coals associated with two fossiliferous limestones makes its appearance directly under the Homewood sandstone, and extends almost uninterruptedly across the Ohio field to Hanging Rock. It was first fully described from the vicinity of Mercer, Pennsylvania, and named from that locality. When well developed the group presents the succession seen in Section 140, and is 40 to 50 feet thick.

The two limestones are very much alike, except the Lower Mercer is a little darker blue than the Upper, and is the more persistent. Both are crowded with fossils and are frequently cherty, some of the famous "flint ledges" of Ohio being made by one of these beds. Each limestone usually carries an iron ore on its top of the variety known as "block" ore. The Upper Mercer is known as the Zoar limestone in many portions of Ohio, and its ore is called by several terms, among which are "Dunkel Block," "Franklin Block," "Main Block," "Big Red Block," etc. The Lower Mercer was formerly known as the "Blue" limestone, and its corresponding ore as the "Blue Limestone Block," "Little Block," etc.

The Mercer coals are generally two, the upper one coming under the Upper Mercer limestone and the lower one under the Lower Mercer limestone. Occasionally there is also a coal on top of each limestone, but these beds are sporadic, and hence do not merit a designation, though Orton has applied the name "Tionesta" to the upper one in Ohio, as the writer did in Report Q^2, on Lawrence County, Pennsylvania.

These Mercer coals are generally rich in ash, and are seldom mined on a commercial scale, although they are quite persistent from western

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Pennsylvania all around the northern margin of the Ohio coal field. Both of them occasionally become cannel in Ohio, the upper being the Strawbridge cannel of Holmes County and the Bedford cannel of Coshocton, according to Orton, while the lower coal is the Flint Ridge cannel of Licking County. Neither of these beds seldom exceeds 3 feet in thickness, and they are more frequently only 1 or 2.

Eastward from Mercer and Lawrence Counties, Pennsylvania, the limestones disappear from this group and the coals thin away, except around the northern rim of the coal field, where, in McKean County, the Alton coal group of Ashburner probably represents the Mercer coals, so that usually only one is left, and it is generally quite impure. This bed has received a different name for nearly every locality where it attains workable thickness. Rogers called it the Tionesta coal in Forest County, Pennsylvania, and it is the Mount Savage bed of Somerset. Along the north Potomac River it frequently appears in the cuts of the West Virginia Central Railroad, and is there known as the "Railroad seam." It has been mined for local use just above Valley Falls, Taylor County, West Virginia, where it lies near water level, and is 4 feet thick, with a slate near center. It always presents a coarse structure, and no first-class fuel is ever obtained at this horizon. Along the New River, and through all the country between it and the Tug Fork, only an insignificant coal, 1 to 2 feet thick, occurs at this level.

The famous Mount Savage fire clay of Pennsylvania and Maryland comes within the limits of the Mercer group, and directly underlies the Mount Savage coal, which it occasionally replaces.

THE CONNOQUENESSING SANDSTONES.

Below the Mercer group there comes the great sandstone horizon par excellence of the Pottsville series. This group is generally triple, there being a massive sandstone at top, then a coal and shale interval, below which is another massive sandstone. These sandstones were first studied by the writer along the Connoquenessing River, in Lawrence County, Pennsylvania, and they were designated from that stream. The Massillon sandstone of Newberry represents only a portion of the group; otherwise it would have precedence in nomenclature.

Each of these sandstone members is from 40 to 50 feet thick, though occasionally the shale and coal separating them thins out and they coalesce into one mass 150 to 200 feet thick, or even more. They are generally quite hard, the quartz grains being finer and more compactly arranged than in the Homewood sandstone above. The color is more frequently yellowish white than any other, though sometimes it is gray.

The Quakertown coal comes between the two sandstone members of the group. It seldom exceeds 2 feet in western Pennsylvania or eastern Ohio, and unless it should be the "Jackson shaft," or "Wellston" coal, it does not seem to attain much importance in that State, though it is often present in the series as a thin bed, being represented in the

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Hanging Rock section (147) by number 13, which is only 2 feet thick, slate and all.

East from the Mahoning River no workable coal is known at this horizon in Pennsylvania, though a thin coal or black slate is often present.

THE NEW RIVER COAL GROUP.

The great development of coal in the middle and lower half of the Pottsville series along New River, West Virginia, has given name to this group. Although there are thin representatives of the group in nearly every section of the Pottsville which is exposed in Pennsylvania, yet only around the northwestern margin of the field in that State is any valuable coal found at this horizon, namely, the Sharon coal of Mercer County. This bed occurs in pockets and isolated basins, in the western part of Mercer, where it is 3 to 5 feet thick, and a "block," or open-burning coal of great purity. It enters Ohio in the same patchy condition, and extends through Mahoning, Trumbull, Portage, Summit, Stark, Medina, and Wayne Counties of northeastern Ohio, and it is probably the "Jackson shaft" or "Wellston" seam of Jackson County in southern Ohio. In all cases it is the same open-burning, pure fuel, very low in ash and sulphur.

This Sharon bed and its thin rider appear to represent all the coals in the New River group, and hence it can not be called identical with any one of them, though according to Prof. Fontaine the flora of the Sharon roof shales is very similar to that found in the roof of the Quinnimont bed on New River. These roof shales of the Sharon coal through western Pennsylvania and across Ohio are a very characteristic feature. They begin directly under the Connoquenessing sandstones, and are often 40 to 50 feet thick, of a dark blue color, and generally contain much iron ore (carbonate) in nuggets and bands. These shales show the same character at Hanging Rock (Section 147), in southern Ohio, as they do on the Mahoning at the east.

In passing southward from Pennsylvania, along the Alleghany Mountain region, one of these New River beds thickens up to 3 feet in Garrett County, Maryland, just east from the West Virginia line, and has there been mined for local use on the land of Mr. Browning. It comes near the base of the Pottsville series, is quite soft and pure, and exhibits the same coking type as these coals all do on New River. One of these beds is also workable along Shaver's Fork of Cheat River, east from the Beverly Valley. This coal group, which is well shown in the Black Water section (133) of Tucker County, grows in importance southwestward through Randolph, Webster, Greenbrier and Nicholas Counties, into Fayette, where at Nuttallburg on New River we find the type section of the group (No. 151), which there incloses three workable coal beds besides several too thin to be of economic importance. The three workable beds are, in descending order, the Nuttall, Fire Creek, and Quinnimont, with the intervals separating them shown in Section 151.

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THE POTTSVILLE CONGLOMERATE CLIFFS AND DÉBRIS ON NEW RIVER, WEST VIRGINIA, NEAR FAYETTE.

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These coals vary from 3 to 5 feet in thickness along New River, and are the ones from which the celebrated New River coke is now manufactured. The Nuttall is the most regular and persistent, being the only one which dips below water level at the north with a workable thickness.

They are all quite soft, very low in ash and sulphur, and rich in fixed carbon, making coke of the greatest purity.

The Fire Creek and Quinnimont beds are quite irregular in their distribution and thickness, but both of them furnish much good coal on New River. I have termed the lowest bed the Quinnimont, but the stratigraphical horizon of the Quinnimont seam is not yet settled, since it may prove identical with the Fire Creek bed, but all the coal operators agree that there are three workable coals on New River, and that Nos. 11, 16, and 18 of Section 151 are these three beds, whatever their identity with reference to the Fire Creek and Quinnimont localities may be.

Southwestward from Fayette County towards Raleigh, Mercer, and McDowell, the New River coals still continue to increase in thickness and importance, culminating in the great bed at Pocahontas, in the edge of Virginia.

Section on Crane Creek, West Virginia, near Pocahontas, Virginia.—Section 152 shows the succession of these coals on Crane Creek, a tributary of Blue Stone, a few miles northeast from Pocahontas. Here the Pocahontas coal is divided into two benches by a layer of shale 5 feet thick, but at Pocahontas it exhibits the following structure:

	Ft.	in.	Ft.	in.
Coal	9	6	10	8
Shale	0	4		
Coal	0	10		

There is a bony streak about 2 feet below the top of the coal, but it is not rejected in mining.

Section at head of South Elk Horn Creek, McDowell County, West Virginia.—Across the Flat Top Mountain divide from Pocahontas, around the head of South Elk Horn Creek, in McDowell County, this coal exhibits the following structure:

	Ft.	in.	Ft.
Coal	3	8	9
Bony coal	0	8	
Coal	2	3	
Slate	0	1	
Coal	2	4	

Section on East Branch of Simmons Creek, Mercer County, West Virginia.—On the east branch of Simmons Creek this coal shows as follows:

	Ft.	in.	Ft.	in.
Coal	2	2	8	10
Slate, blue	0	4		
Coal	6	4		

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Section on west branch of Flipping Creek, Mercer County, West Virginia.—On the Walker tract, west branch of Flipping Creek, the coal has this structure:

	Ft.	in.	Ft.	in.
Coal	2	6	18	6
Dark shales	10	0		
Coal	6	0		

Section on Pinnacle Fork of the Guyandotte River, Wyoming County, West Virginia.—Just before this coal passes under the level of the Pinnacle Fork of the Guyandotte River west from Flat Top Mountain it exhibits the following structure:

	Ft.	in.	Ft.	in.
Massive sandstone				
Coal	1	4	14	8
Fire clay	3	0		
Sandy shale	5	0		
Coal	5	4		

This coal was numbered III in the original section published from Pocahontas by Maj. Jed. Hotchkiss, and it is frequently known by that name. Major Hotchkiss thinks the Pocahontas bed identical with the Quinnimont of New River, but the writer can not yet satisfactorily correlate this bed with any of the New River coals which have been mined.

The coal from the Pocahontas seam is quite as pure and valuable for coke and general fuel purposes as any in the New River field, and, in fact, is the same kind of coal.

Two other beds of 4 to 5 feet in thickness occur in the hills above the Pocahontas vein, but so far they have not been mined to any extent, as they are not regular in thickness and the great bed below monopolizes the present mining operations.

THE SHARON CONGLOMERATE.

The interval below the Sharon coal in Ohio and western Pennsylvania down to the base of the Pottsville series is often occupied by a massive conglomerate, and when it is absent the coal with its under-clay rests directly on the Lower Carboniferous beds. This conglomerate stratum was considered a separate member of the series by the Ohio geologists and as representing the entire No. XII conglomerate of Rogers in Pennsylvania.

But later studies have shown that it is simply the basal member of this series. When well developed in Ohio it is very coarse, being a mere mass of pebbles from a pea to an egg in size. There is no single stratum around the southeastern margin of the Appalachian field that will exactly compare with the Sharon conglomerate in physical aspect, though local streaks in all these great sandstones are quite as pebbly, but just as the Sharon coal is represented by several beds in the New River section, so the Sharon conglomerate, only 20 to 40 feet thick in

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Pennsylvania and Ohio, is on New River represented by 300 to 400 feet of shales, sandstones, and conglomerates.

In northern Pennsylvania the Olean conglomerate of Bradford County and the Garland conglomerate of Warren have been shown by Mr. John F. Carll to be identical with the Sharon stratum, and they also resemble it very much in physical characters. The coarse type of the Sharon conglomerate appears to be confined to the northwestern rim of the Appalachian field, since it disappears southward under the other members of the series.

THE LOWER CARBONIFEROUS BEDS.

Below the base of the Pottsville series come the red shales and limestones of the Mauch Chunk series, and then succeed the gray sandstones of the Pocono, the lowest series of the Carboniferous system.

Thin coals occur locally in both of these members of the Lower Carboniferous in Pennsylvania and West Virginia, but nowhere in these States, nor in Ohio, does any merchantable bituminous coal exist in this portion of the Carboniferous.

The Tipton Run coals of Blair County, Pennsylvania, have been cited as occurring in the Pocono sandstone series for the last thirty-five years, and this conclusion is reiterated by Mr. Ashburner in a special report made as late as 1885 (Pennsylvania Geological Survey, Annual Report, 1885, p. 250), but a single glance at the fossil plants occurring in the roof shales of the coals now mined there proves that they belong to the Lower Coal Measures, or Alleghany River series, and not to the Pocono, their apparent stratigraphical position being the result of displacement, so that although the Pocono series is reported to contain valuable coal beds in Montgomery County, Virginia, it certainly does not in any of the three States covered by this report, and hence a further consideration of the Lower Carboniferous beds is not germane to this publication.

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